COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

February 1957

Carbon Steam Electric Plant, Utah Power & Light Co.

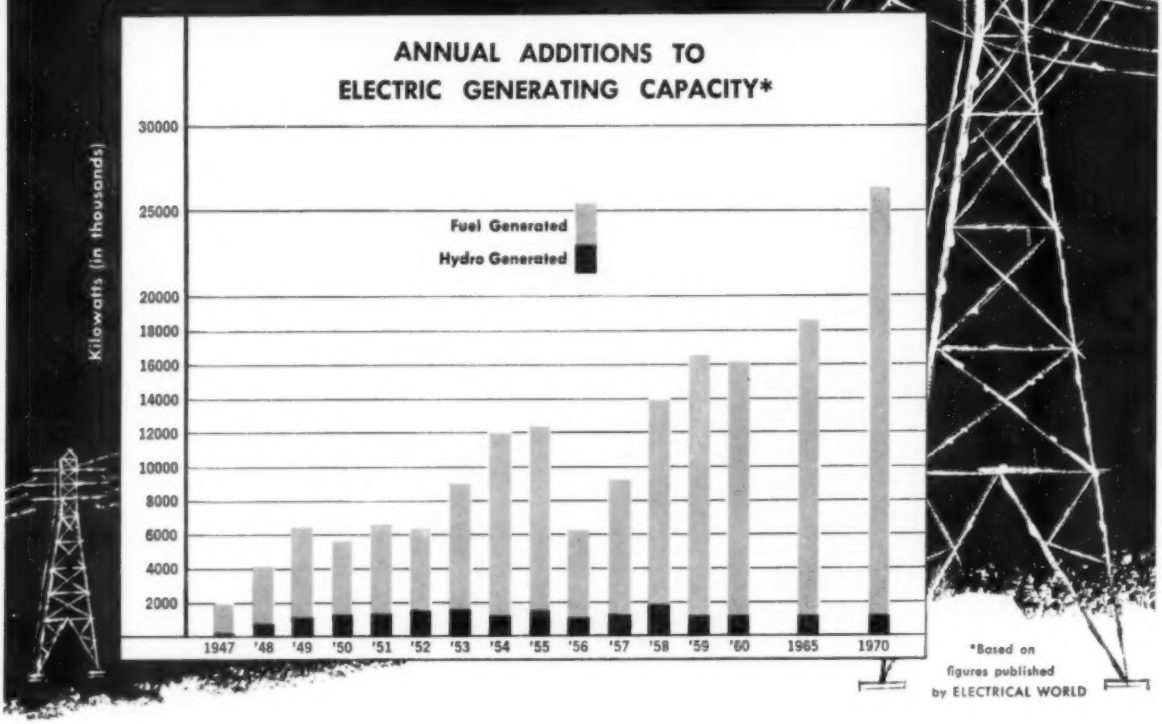
Slagging Furnace Developments

Forced Outage Rates, Boilers and Turbines

Heat Balance Studies in Textile Plants

Thermal Problems of Atomic Power Stations

Why Combustion is accelerating its expansion program



The chart shows the rate at which America's utility industry has been expanding for the past decade and its projected rate of expansion to 1970. What this rate of growth means is dramatically illustrated by the fact that the total new capacity to be installed in the next decade will substantially exceed the total capacity the utility industry has attained in the 75 years it has been in existence.

Because electrical consumption reflects our national prosperity and living standards, this chart also indicates the progress we have been making as a nation and the progress we can anticipate for some years to come. It is doubly significant to us at Combustion since the largest part of our dollar volume comes from sales of utility boilers, and the second largest part from sales of boilers and other equipment to industry whose annual rate of growth roughly parallels the rate of power expansion.

To keep abreast of power expansion, Combustion increased its manufacturing capacity *more than 50 per cent* in the five-year period ending in 1955. And it is now engaged in the biggest expansion program in its history – not only to assure its ability to meet the ever-growing demand for conventional boilers, but also to prepare itself for a major role in the rapidly developing field of nuclear power.

In its expansion, as well as in its research and development work, Combustion's objective is to build boilers today that will set *tomorrow's* standards of performance. Whether your steam requirements be large or small, you can depend on C-E Boilers to give you the best in economy and reliability.

COMBUSTION ENGINEERING C-E

B-975

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200 Madison Avenue, New York 16, N. Y.

all types of steam generating, fuel burning and related equipment; nuclear reactors; paper mill equipment; pulverizers; flash drying systems; pressure vessels; soil pipe

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 28 **No. 8**

February 1957

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BPA

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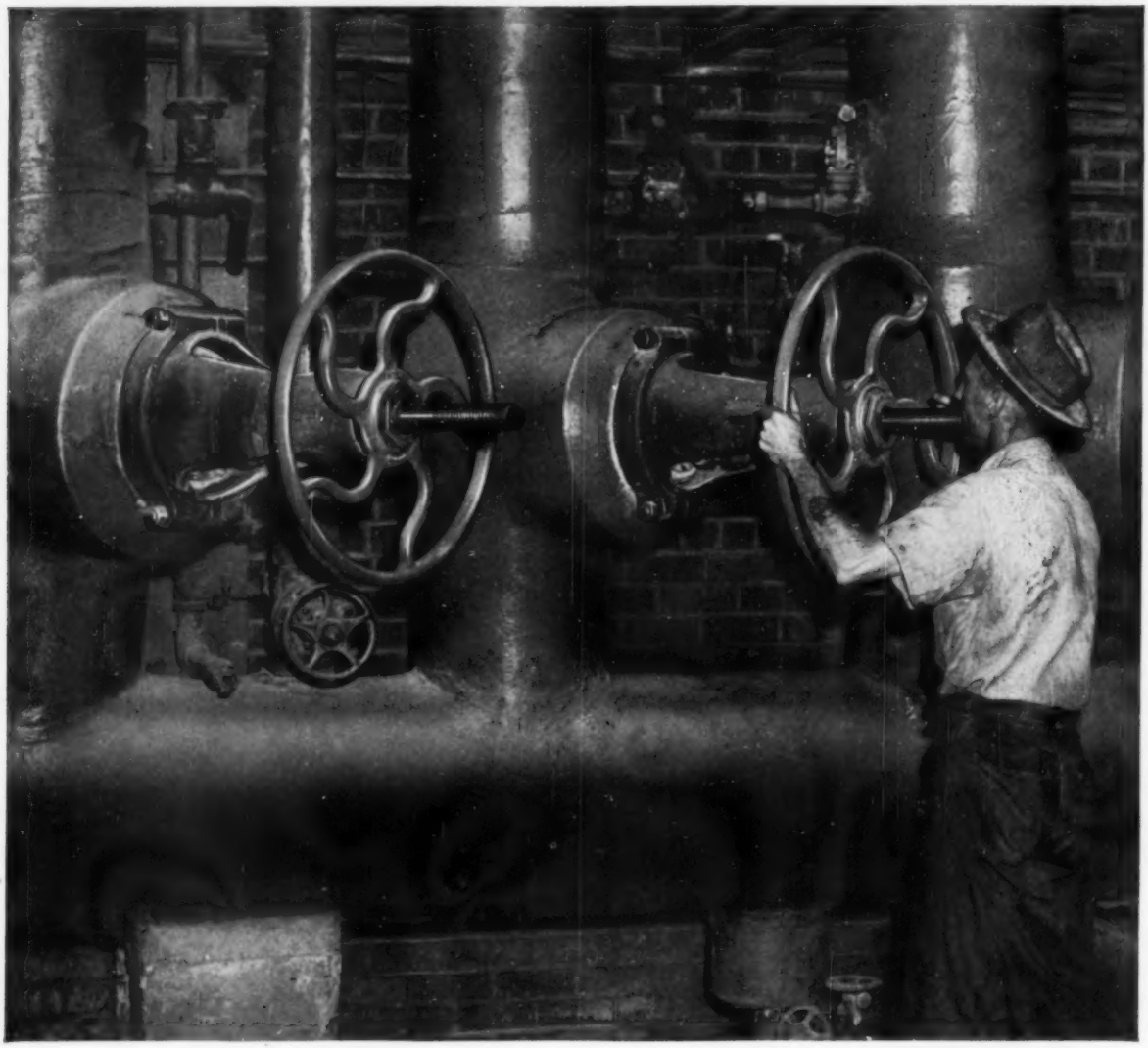
No Bonnet-Joint Maintenance—No Bonnet-Joint Leakage



These valves helped the maintenance crew win a losing battle

This process industry plant saw the danger signal. Servicing leaky valve bonnet joints was taking too much time. Other important maintenance work was being neglected.

That's why, in 1947, when expanding the power plant, Crane Pressure-Seal Bonnet Gates were chosen for main steam service as shown above. Working pressure: 600 psi at 725 deg. F.

These Crane valves need no bonnet joint maintenance. The joint is leakproof—sealed tight by internal fluid pressure. Crane alloy seats and flexible wedge disc make closure tight and easy.

To date, the Crane Pressure-Seal Gates have given this plant over 9 years' uninterrupted service. The maintenance crew hasn't touched them except for routine care.

Full information on these modern power service valves is given in Circular AD-1936. Get a copy from your Crane Representative or by writing to address below.

Ask for Circular AD-1936

CRANE VALVES & FITTINGS

PIPE • PLUMBING • KITCHENS • HEATING • AIR CONDITIONING

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Hall Industrial Water Report

VOLUME 5 FEBRUARY 1957 NUMBER 1

Unscheduled Boiler Outages Are the Hobgoblins of Steam Plants

With demand chasing capacity like the famed headless horseman, unexpected loss of a boiler can really be a nightmare. Routing these nightmares by helping operators to keep steam plants trouble-free is the function of chemical engineers skilled in water technology. Hall Laboratories assists thousands of plants to keep their boilers on the line.

Package Boilers Operate Continuously

Three shifts a day, seven days a week, for over five years, with 100 percent make-up of zeolite softened water, the two-drum package-type boiler at a chemical manufacturing plant in Pittsburgh has performed without one unscheduled outage due to water.

The boiler is a 25,000 pounds per hour unit with continuous one and one-half inch floor, wall and roof tubes. Hall engineer L. C. Bishop reports that these tubes have never had to be acid cleaned nor turbined. Plant management was immensely pleased when a recent inspection showed the tubes and drums to be virtually like new.

This record is a tribute to the careful water conditioning work done by the operating men under the guidance of Hall Laboratories.

Spring Exam No Terror At This College

For some years a college in Massachusetts had treated boiler water with trisodium phosphate in a hit or miss manner. Each spring the boiler tubes were so dirty with sludge and scale that the engineer had to clean them by running a knocker turbine through the tubes and following up with a cutter turbine.

A couple of years ago the college retained Hall Laboratories to set up more satisfactory water conditions. The last time the boilers were inspected it was no longer necessary to use the knocker turbine. As a matter of fact, the cutter turbine was used only as a precautionary measure and the time spent on the job was only half that previously required.

J. A. Gregory, the Hall engineer who services the plant, points out that this job is a good example of how a Hall engineer, with the co-operation of the operating men, can clean up a bad boiler deposit problem.

Value of Water Treatment No Day Dream

G. W. Rudolf and T. A. McConomy, engineers in Hall's Washington, D. C. office, recently inspected three boilers at an Atlantic Coast shipbuilding company.

One of the boilers had been retubed and had operated with water conditions recommended by Hall since being returned to service. The second had operated about eight months without boiler water treatment and then four months with Hall recommended water conditions. A third boiler had operated for approximately eight months without treatment.

The first boiler was found to be free from scale and corrosion with just a very small amount of loose sludge in the mud drum. There was a large accumulation of loose scale in the mud drum of the second boiler, indicating that proper water conditions were resulting in removal of the scale which had been deposited when no water conditioning was practiced. The third boiler was very badly scaled and turbining was necessary to put it in shape for further operation.

With this clear-cut evidence, the plant operating men were completely convinced of the value of Hall supervision of water conditioning.

Expert Diagnosis Ends Plant's Troubles

Unhappy about the corrosion and deposits occurring in their steam plant, a Canadian rubber manufacturing company sought out Hall Laboratories to help them with their problems.

J. S. Sullivan, one of the service engineers in Hall's Toronto office, conducted a survey of the boiler and condensate systems as a first step in bringing the plant to trouble-free operation. Boiler water conditioning for scale prevention was necessary, but by measuring corrosion rates in the condensate systems Sullivan was able to show that condensate treatment was unnecessary.

After setting up a regular chemical feeding schedule and prescribing control tests and procedures, Sullivan nursed the plant along during frequent service visits, suggesting desirable changes as treatment progressed.

A recent boiler inspection report stated that the boiler was in very good condition internally. This is the second unit to receive such a favorable report since the plant started to use Hall system.

When the editors of the Encyclopedia of Chemical Technology wanted a concise discussion of "Water, Industrial" for the final volume of their series published in 1955, they asked Dr. Everett P. Partridge, Director of Hall Laboratories, to write it. Reprints have been distributed recently to Hall clients. If you would like a copy of this 21-page chapter, it is yours upon request.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information write, wire or call Hall Laboratories, Division of Hagan Chemicals & Controls, Inc., Hagan Building, Pittsburgh 30, Pa.

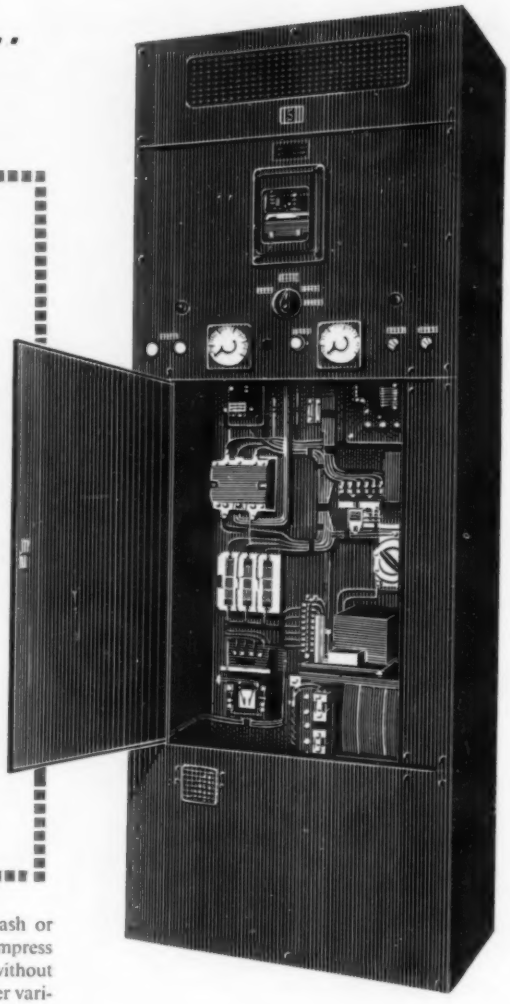
Water is your industry's most important raw material. Use it wisely.

Hall Laboratories—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water

New Automatic Precipitator Control by

WESTERN PRECIPITATION

offers many vital advantages...



1 LONG LIFE

This new control has indefinite life expectancy under all types of operating conditions. There are no tubes to replace, no high speed relays, counters, or timers to maintain. All circuitry consists of rugged "static" devices that have unusually long life!

2 RELIABILITY

Optimum Precipitator power input is maintained regardless of operating conditions. The sensing control is simple, positive, accurate—and automatically evaluates the spark "Power Value" (intensity and frequency)—not just frequency or intensity alone.

3 STABILITY

Under short circuit, open circuit or other varying conditions, this control is completely stable and inherently trouble-free!

4 MODEST COST

Modest initial cost coupled with negligible maintenance assure optimum operating efficiency (therefore lower operating costs) throughout many years of continuous service.

WHEN using a Cottrell Precipitator for collecting dust, fume, fly ash or other suspensions from industrial gases, it is essential at all times to impress on the high voltage system the highest possible voltage and current without "flashover". Depending upon gas conditions, dust loading and other variable factors, the optimum voltage and current requirements vary widely from one minute to the next. Therefore, the vital importance of a simple, trouble-free and highly sensitive Precipitator Control is self-evident.

This new Western Precipitation Automatic Precipitator Control—*a product of the organization that has consistently led in the application of Cottrell Precipitators for industrial gas cleaning* — combines vital advantages found in no other competitive equipment. Our nearest representative will be glad to supply complete details. Or write direct!

Why not modernize your present out-dated Precipitator installation? The Western Precipitation Automatic Precipitator Control can be installed on any Cottrell unit. For further information contact our nearest office!

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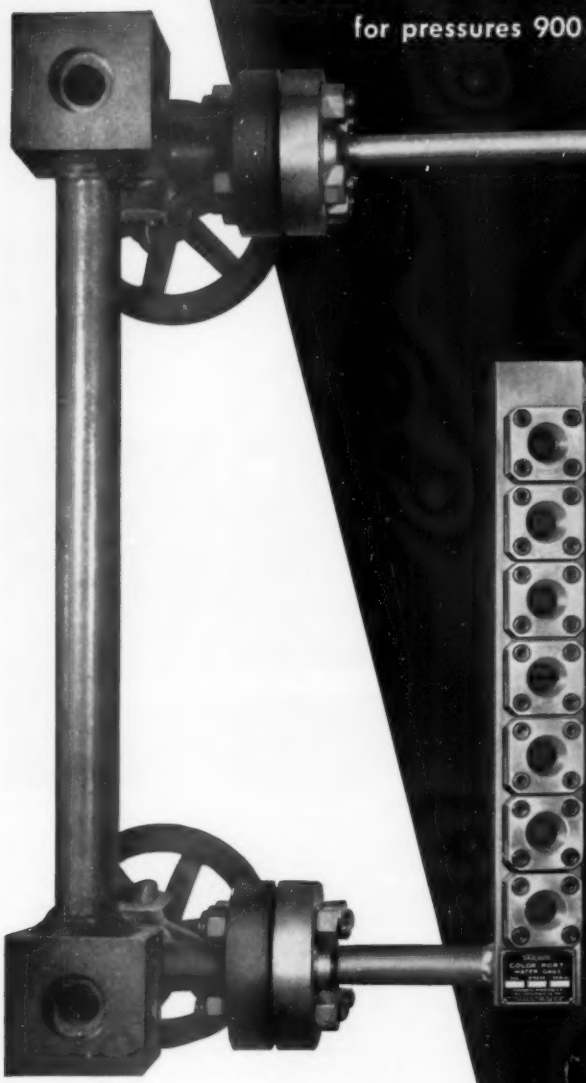
BOILER WATER LEVEL GAGE

for pressures 900 to 3000 psi



- *two-color readings!*
- *reduced maintenance!*
- *increased availability!*

Now Yarway offers brilliant two-color boiler water level readings, combined with simplicity of gage maintenance and increased availability.

With the new Yarway Color-Port Gage, water space shows green, steam space shows red. A full gage is all green and an empty gage all red.

The Color-Port Gage is *serviced quickly in place* by simple replacement of individual cover-glass assemblies. Each cover assembly is held solidly in place by four socket head capscrews and the "floating assembly" design applies safe predetermined loads on glass ports, reducing thermal shocks, and permitting faster warm-up. *Increased availability means longer service life.*

Side view of Yarway Color-Port Water Level Gage with illuminator, circulating tie-bar and Welbond gage valves.

Write today for new Bulletin WG-1814, completely describing Yarway Color-Port High Pressure Water Level Gages.

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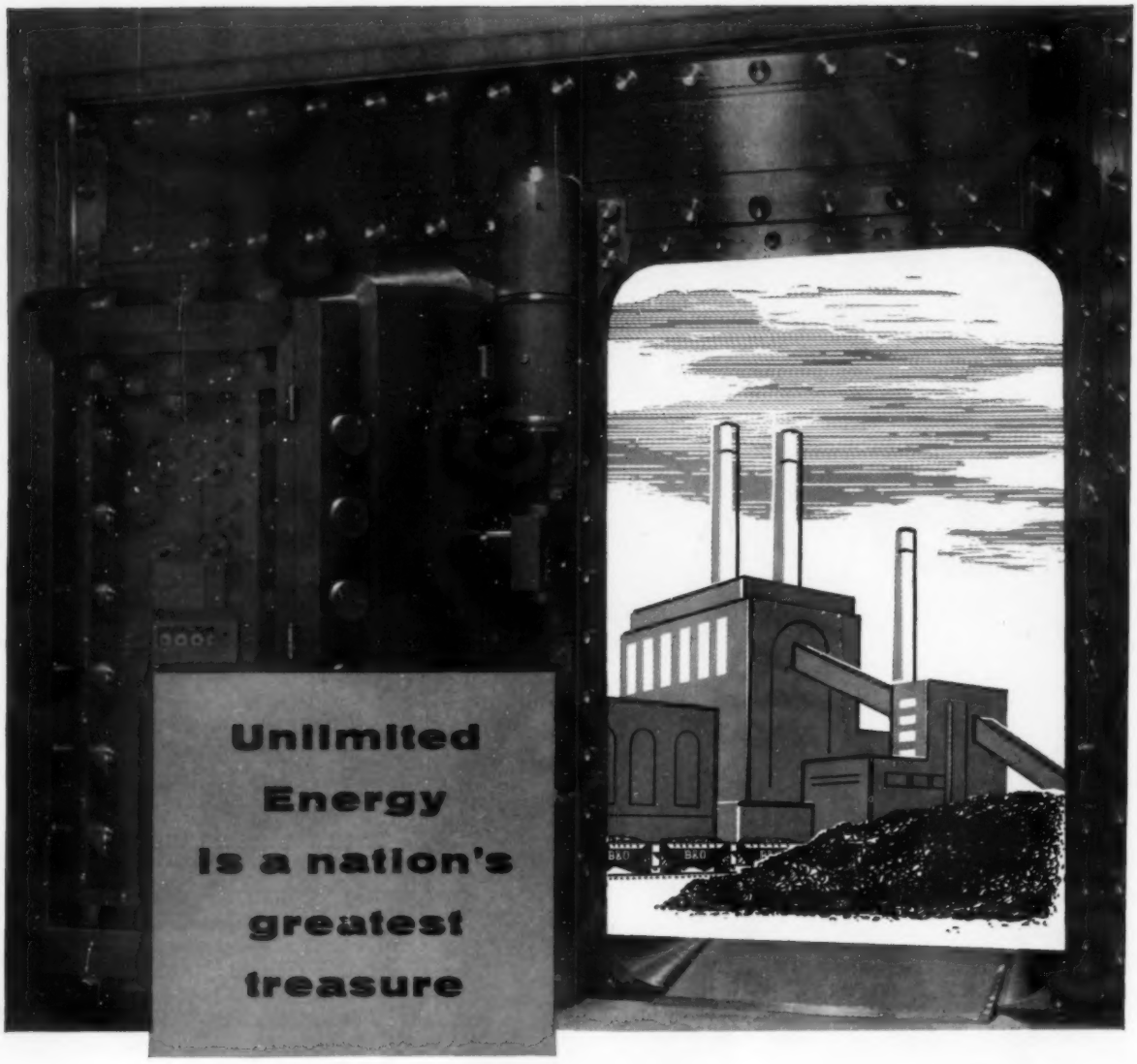
YARWAY® WATER LEVEL GAGES



Modern industrial might comes from nature's harnessed energy. This nation's greatest single energy resource is found in its tremendous reserves of Bituminous coal.

As population increases—as living standards rise, vast additional amounts of energy will be required—and found in Bituminous—*the fuel with a future.*

Fields served by B&O contain known reserves of more than 8 billion tons suitable for every purpose. The nation can safely *bank on bituminous* treasures like this and on B&O operators to mine and supply it in greatest quantities, with increasing efficiency at stable-low-cost. *Ask our man!*

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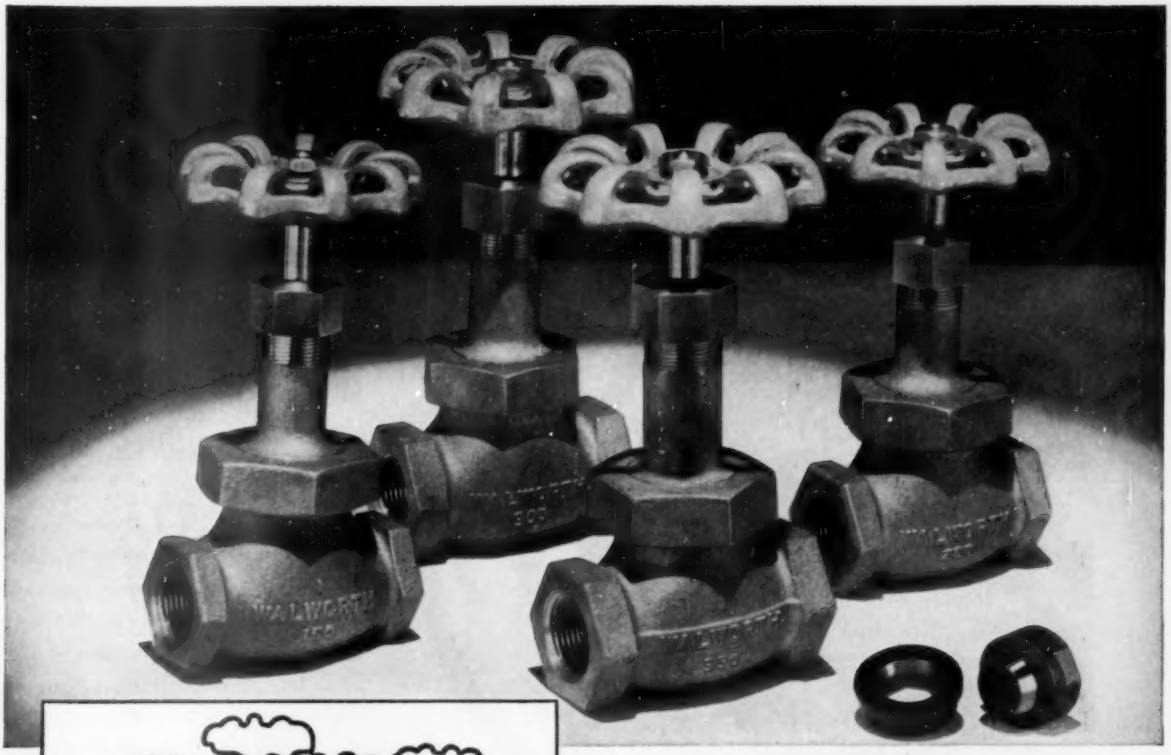

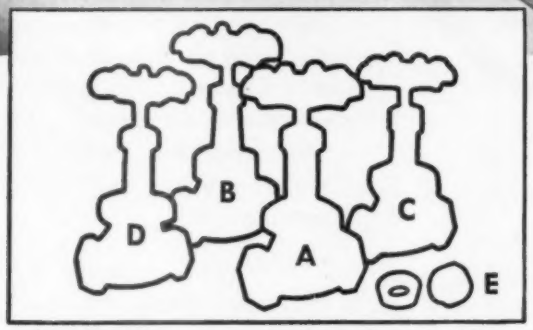

A — No. 225P.....350 WSP 550F, 1000 WOG
B — No. 260P.....300 WSP 550F, 600 WOG
C — No. 245P.....200 WSP 550F, 400 WOG
D — No. 237P.....150 WSP 500F, 300 WOG
E — "500 Brinell" Stainless Steel Plug Type Seat and Disc

Walworth offers four lines of Bronze Globe Valves with stainless steel, plug-type seats and discs. Advantages of these valves include:

• **Stainless Steel Plug-Type Seats and Discs,** heat-treated to a minimum of 500 Brinell hardness reduces wire-drawing to a minimum. Seats and Discs are machined and fitted simultaneously, assuring perfect mating.

• **Deep Stuffing Boxes with Glands** are fitted with reinforced, molded packing. Valves can be repacked under pressure when fully opened.

For Longer Bronze Valve Life . . .

"500 BRINELL" PLUG-TYPE STAINLESS STEEL SEATS AND DISCS

150 lb. 200 lb. 300 lb. 350 lb.

• **Oversize Stems,** made of high tensile strength silicon-bronze, assure long life.

• **Rugged Body Hexes,** are flat on top; do not interfere with wrench gripping body-to-bonnet union ring connection.

• **Bodies,** made of Composition M bronze (ASTM B61), have ample wall thickness to provide high safety factor.

• **Patented Handwheels** are air-cooled and designed with a "finger-fit grip." Makes turning easy even when wearing greasy gloves.

• **Identification Plates** secured by lock-washer under stem nut, show Figure Number of valves and make re-ordering sure and easy.

FOR COMPLETE INFORMATION, SEE YOUR WALWORTH DISTRIBUTOR OR WRITE FOR ILLUSTRATED CIRCULAR

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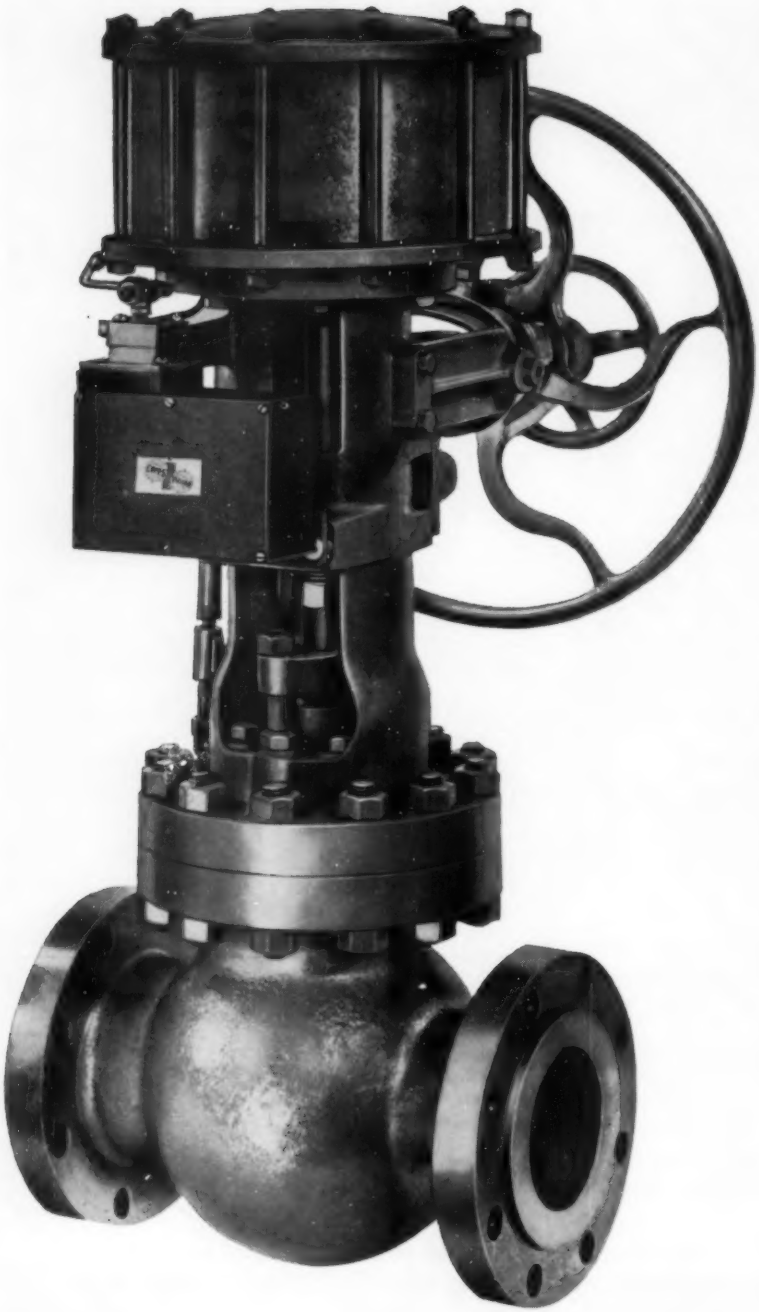

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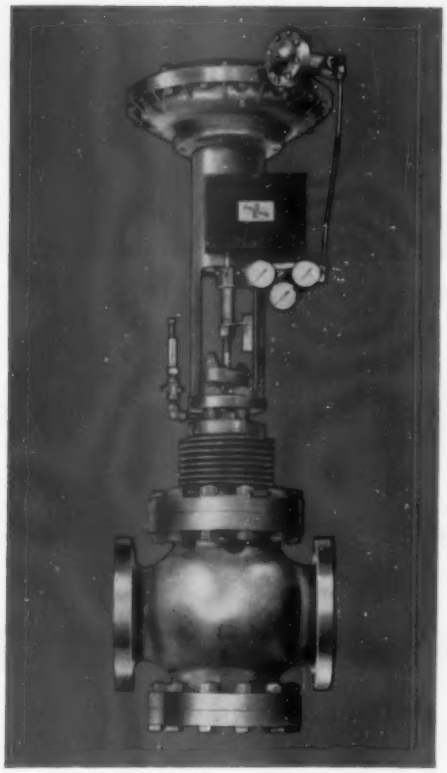
Piston-Type CV-P. For high-duty service. Extremely precise positioning gives you superb operating characteristics. Rangeability is high. Response can be characterized to meet your operating requirements. Designed for those applications which demand the ultimate in valve-operating force . . . where you want the finest valve money can buy. Hand wheel is optional.

Diaphragm-Type CV-D. Either direct or reverse acting. High rangeability. Optional features include: Cooling fins and lubricator for stuffing box that will maintain low friction over longer packing life; hand wheel for emergency operation.

the right valve for more jobs!



Now you can apply high-quality Copes-Vulcan Valves to any application, at unlimited pressures in sizes up to 12 inches. Simplified design gives you this new versatility, plus high standards of performance for broader applications. Too, you will get the Copes-Vulcan custom-design, with ports exactly suited to the requirements of your operation.

Get in touch with your Copes-Vulcan man. He can help you apply the new Copes-Vulcan Valves to your control requirements. You'll get real dollars-and-cents savings in operational cost with less downtime in even those troublesome spots where ordinary valves are inadequate. Write for Bulletin 1027.

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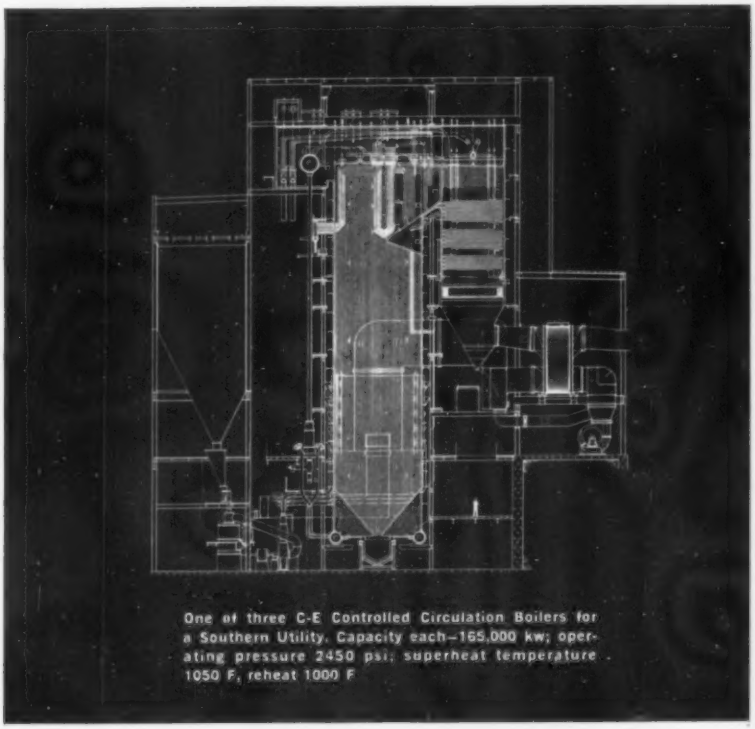
BLAW-KNOX
1906-1956



One of three C-E Controlled Circulation Boilers for a Southern Utility. Capacity each—165,000 kw; operating pressure 2450 psi; superheat temperature 1050 F, reheat 1000 F

2400

The Outstanding

In 1956, the most notable trend in power plant practice was the large-scale adoption of the 2400 lb pressure cycle. In this pressure range, the utility industry purchased more than twice as many C-E units as they did in 1955. These units range in size between 125 mw and 325 mw. Operating pressures ***at the turbine throttle*** range from 2400 psi to 2620 psi. Of course, all are Controlled Circulation Boilers and 3 units are of the C-E Sulzer "once through" design. All units are equipped with C-E Tilting Tangential Burners and, in the larger sizes, a number are of the C-E Twin Furnace design.

COMBUSTION

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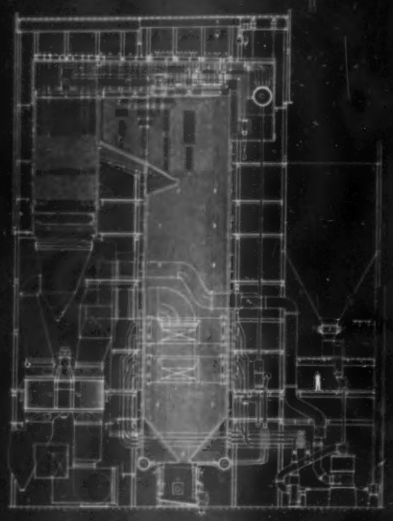
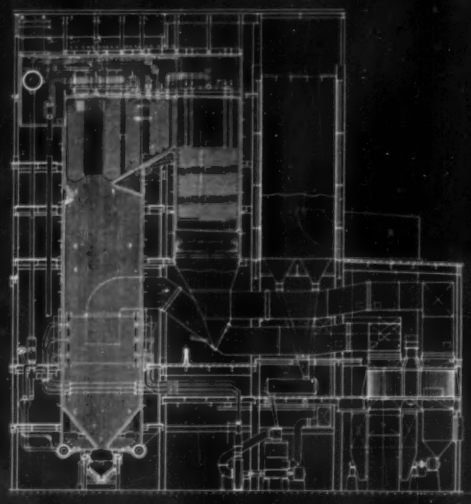
ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;



One of two C-E Controlled Circulation Boilers for a Mid-Western Utility. Capacity each — 200,000 kw; operating pressure—2500 psi; superheat temperature 1050 F, reheat 1050 F



One of two C-E Controlled Circulation Boilers for an Eastern Utility. Capacity each—200,000 kw; operating pressure—2460 psi; superheat temperature 1050 F, reheat 1000 F

PSI

Power Trend of 1956

Orders placed for C-E Boilers in this pressure range, including three purchased prior to 1955, now total 32 units with an aggregate capacity of over 5,500,000 kilowatts. This remarkable record is attributable to the proven suitability of the C-E Controlled Circulation Boiler for the highest range of sub-critical pressure and to its outstanding performance, especially with respect to availability.

The capacity of all C-E Controlled Circulation Boilers ordered since 1950—covering a range of turbine throttle pressures from 1500 to 2620 psi—now totals well over 16-million kw of which approximately 5½-million kw is in service. The cumulative service of these installations is equivalent to more than 60 boiler years.

As this record demonstrates, Combustion designs have anticipated advancement in power practice and have made a significant contribution to the all-important industry objective of achieving ever lower generating costs.

B-980

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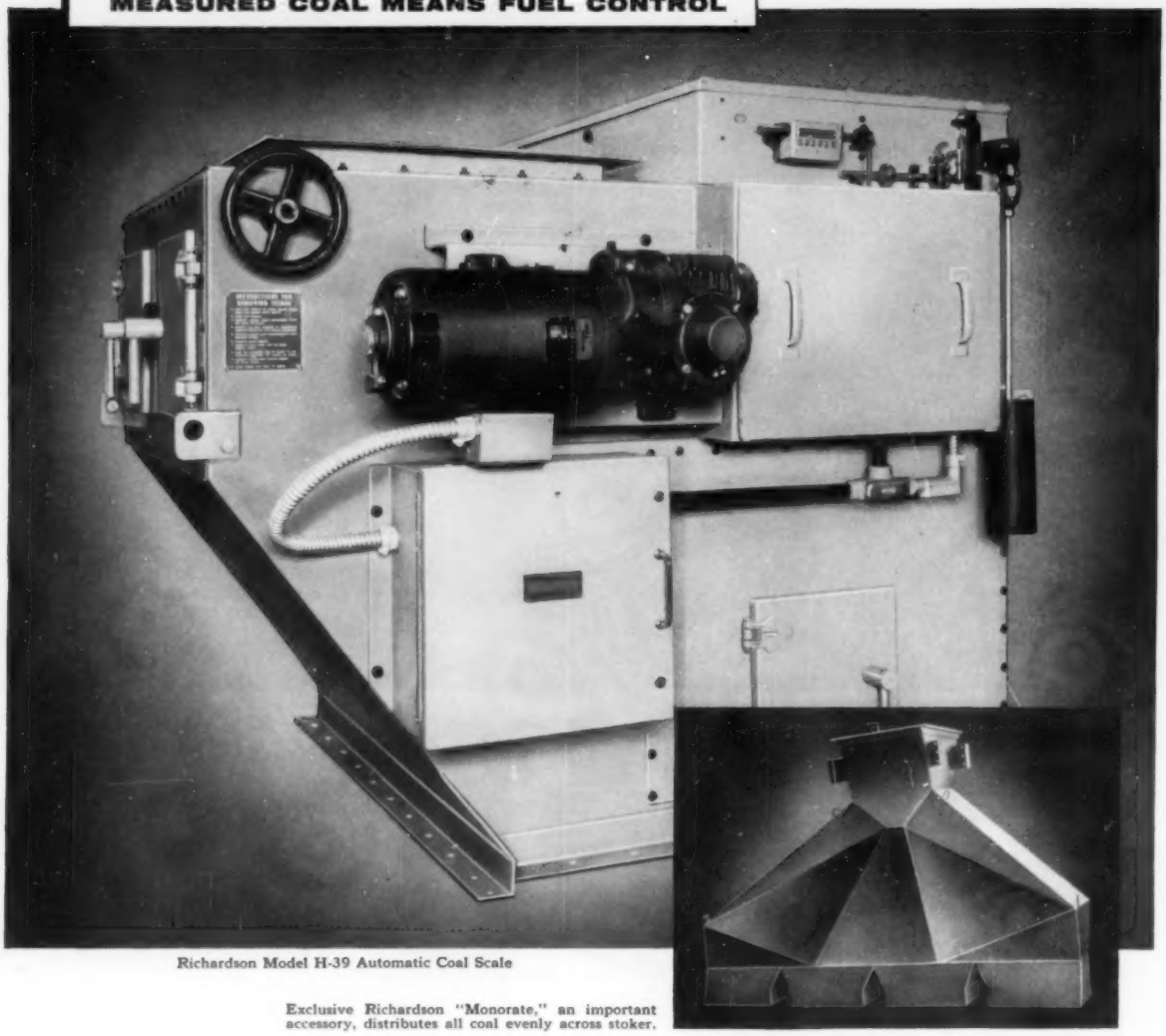
MEASURED COAL MEANS FUEL CONTROL



Richardson Model H-39 Automatic Coal Scale

Exclusive Richardson "Monorate," an important accessory, distributes all coal evenly across stoker.

Automatic fuel control with a Richardson H-39

All Richardson H-39 coal scales feature a LARGE 24" x 24" inlet. Coal moves through freely from bunker to stoker or pulverizer, never "arches" in an H-39 feeder or weighing hopper.

Richardson Coal Scales assure top performance, low maintenance, low operating cost, and trouble-free operation under all boiler-room conditions. They provide a continuous, accurate record of fuel consumption.

All contact platework of stainless steel. Quick, easy access to all parts of scale —all positively dust-sealed. All electrical equipment totally enclosed and installed *outside* of dustproof housing —never in contact with coal dust at any time. Endless belts available. Feeder is removable for maintenance. This scale includes *everything* dictated by 40 years of experience in automatic coal weighing.

For stoker fired boilers, the Richardson Monorate Distributor maintains uniform delivery of coarse and fine coal. No internal baffles. Designed for your conditions.

A nation-wide service organization of Richardson specialists guarantees accurate performance of all Richardson installations. Write today for Bulletin No. 0352A and 1349 for complete information.

Richardson

MATERIALS HANDLING BY WEIGHT SINCE 1902

4604

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R.S.M.
Design features like these help Edward sell more steel non-return valves than any other manufacturer in the world.
B.J.B.

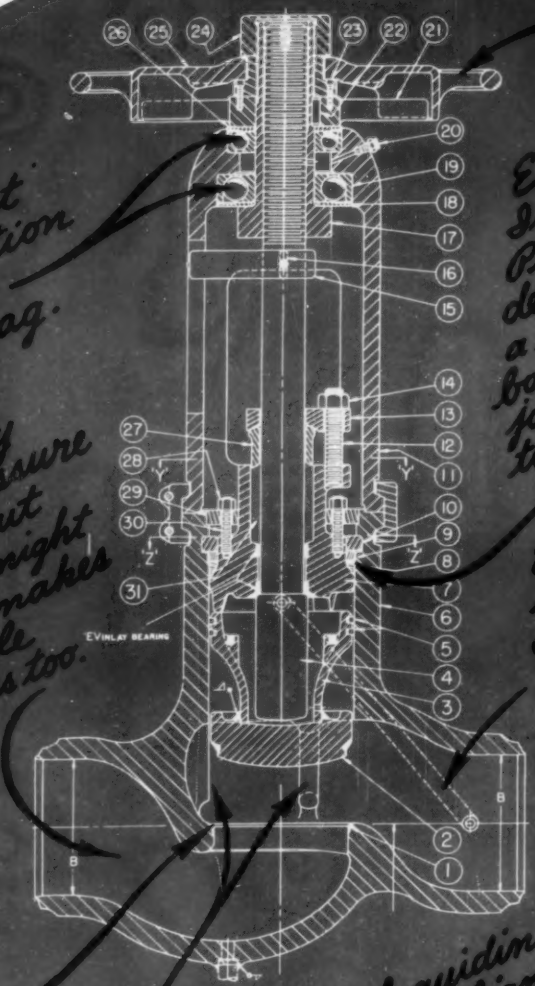
Edward Impactor handwheel seats big valve tightly—allows one man to do the job of three.

ROCKWELL BUILT
Edward Valves

Patented Evalthrust bearing construction eases operation reduces stem drag.

Streamlined body really helps. Pressure drop is only about half what you might guess. Edward makes streamlined angle non-return valves too.

Integral Stellite seat is best. Only Edward has it on large valves.



Edward Improved Pressure Seal design makes a leak proof bonnet joint, is easy to disassemble.

Equalizer aids disk-piston lift, reduces motion and extends life of guiding surfaces.

Full length rib guiding of disk provides perfect alignment, insures true seating and reduces danger of hang ups.

When it comes to steel non-return valves, let's order Edward and have them quote on other valves too.

LIST OF MATERIALS
QUANTITIES ARE FOR ONE VALVE
WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED, THE LATEST REVISION APPLIES

PIECE NO.	NAME OF PIECE	NO. REQ'D	MATERIAL	SPECIFICATIONS	STANDARD NUMBER
1	SEAT	1	STELLITE	RECORD WITH BODY	481
2	DISK	1	FORGED ALLOY STEEL STELLITED	ASTM A182, GRADE F11	227 481
3	PISTON-WELDED TO DISK	1	CAST STEEL	A.S.T.M. A216, GRADE WCB	105
4	GUIDE	1	CAST STEEL	A.S.T.M. A216, GRADE WCB	105
5	PISTON RINGS	2	ALLOY	A.S.T.M. A182, GRADE F5	313
6	BODY	1	CAST STEEL-0.25% MAX CAST STEEL-0.25% MIN CAST STEEL C-0.18% MAX	A.S.T.M. A216, GRADE WCB A.S.T.M. A216, GRADE WCB A.S.T.M. A216, GRADE WCB	105 105 105
7	BONNET	1	CAST STEEL	A.S.T.M. A216, GRADE WCB	105
8	PRESSURE SEAL GASKET	1	ARMCO IRON	MALLEABLE PLATED	502
9	SPACER RING	1	STEEL		
10	GASKET RETAINER	1	UNION	A.S.T.M. A181, GRADE I-1	313
11	STOP	1	CAST STEEL	A.S.T.M. A216, GRADE WCB	105
12	GLAND STUDS	2	ALLOY STEEL	A.S.T.M. A193, GRADE B7	108
13	GLAND FLANGE	1	STEEL-PLATE	A.S.T.M. A283, GRADE C	115
14	GLAND BOLT NUTS	2	STEEL	ASTM A194, GRADE 2	124
15	STEM GUIDE COLLAR	1	STEEL-PLATE	A.S.T.M. A283, GRADE C	115
16	STEM GUIDE KEY	1	STEEL	A.S.T.M. A108, GRADE 1020	122
17	YOKE BUSHING	1	CAST BRONZE	ASTM B148 GRADE 9D-MT	432
18	BEARING WASHER	1	STEEL-CADMIZED	A.S.T.M. A283, GRADE B	115
19	ANGULAR CONTACT BALL BEARING	1		S.K.F. STANDARD	
20	ALEMITE FITTING	1	BUTTON-HEAD INDUSTRIAL	TYPE	
21	CROSSHEAD	1	CAST STEEL	A.S.T.M. A216, GRADE WCB	105
22	CROSSARM KEY	1	STEEL	A.I.S.I. C1020	122
23	HANDWHEEL BUSHING	1	BRASS	A.S.T.M. B62	413
24	HANDWHEEL (SPOKED)	1	STEEL-PLATE	A.S.T.M. A283, GRADE B	115
25	IMPACTOR HANDWHEEL	1	CAST IRON	A.S.T.M. A126, CLASS B	301
26	BEARING WASHER	1	STEEL-CADMIZED	A.S.T.M. A283, GRADE B	115
27	GLAND	1	STEEL-PLATE	A.S.T.M. A283, GRADE B	115
28	BONNET RETAINER NUTS	8	STEEL	A.S.T.M. A194, GRADE 2H	124
29	BONNET RETAINER RING	1	STEEL-PLATE	A.S.T.M. A283, GRADE B	115
30	BONNET RETAINER STUDS	8	ALLOY STEEL	A.S.T.M. A193, GRADE B7	108
31	PACKING RINGS		HIGH TEMPERATURE PACKING		

Edward builds Globe and Angle Stop, Non-Return, Check, Stop-Check, Gate, Blow-Off, Mudline, Relief, Hydraulic, Instrument, Gage, and Special Valves and Strainers.

EDWARD VALVES, INC.
SUBSIDIARY OF ROCKWELL MANUFACTURING CO.
EAST CHICAGO, INDIANA

EDWARD GLOBE NON-RETURN VALVE
PRESSURE SEAL BONNET — WELDING ENDS
GENERAL ASSEMBLY

DRAWN [illegible]
CHK'D O. Peter
APP'D [illegible] DATE: 7-11-56

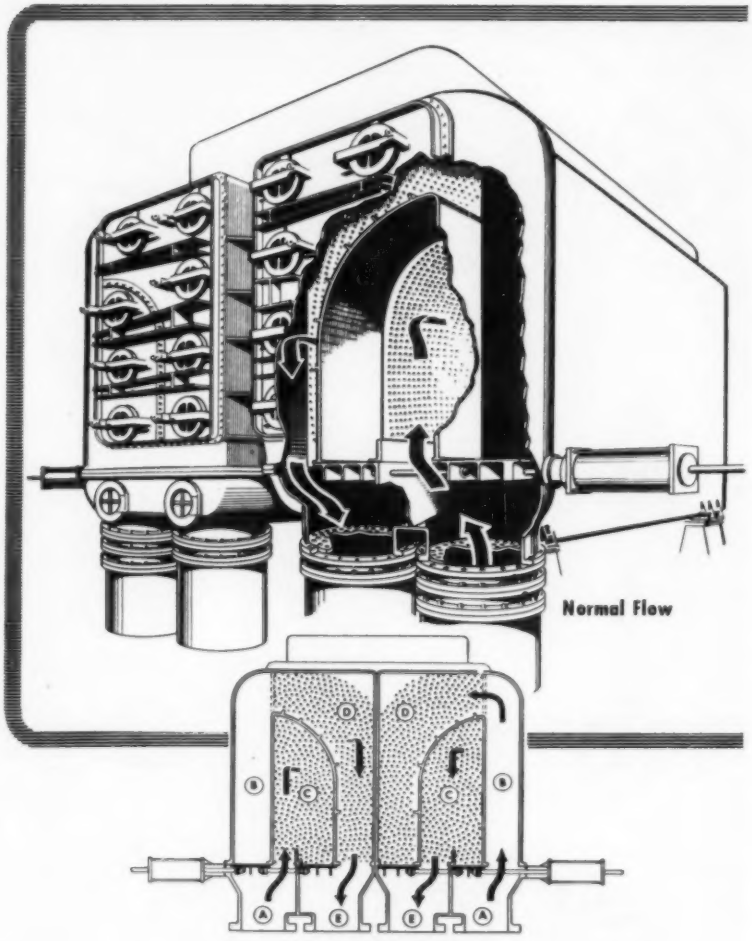
DRAWING NO. AE-3213-6

REVERSE FLOW by C. H. WHEELER
Cleans Steam Condenser Tube Sheets Without Loss of Load

When debris and organic growth collect on the tube sheets of a C. H. Wheeler Patented Reverse Flow Steam Condenser, you don't have to shut it down for cleaning. It cleans itself—without loss of load. Sluice gates arranged within the condenser may be controlled, either electrically or hydraulically, to reverse the flow of cooling water through the tubes. This sudden reverse flow literally flushes away leaves and debris, dislodges crustaceous matter from clogged tubes.

Because of 100% water flow during back flushing, there is only a negligible dip in vacuum momentarily, thus permitting continuous load on the turbine The Reverse Flow Condenser cleans itself in minutes, compared with hours of downtime when tube sheets are manually cleaned. A typical report shows a half-inch loss of vacuum (due to fouled tubes and tube sheets) was restored in five minutes after reversing the flow of cooling water. Often, a C. H. Wheeler Reverse Flow Condenser goes two years or more without shut down for cleaning, depending on the condition of the cooling water.

New, exclusive deaerating features and construction techniques help make C. H. Wheeler Steam Condensers "First in Efficiency." Let C. H. Wheeler Custom Engineer your next steam condenser. Phone or write C. H. Wheeler Manufacturing Co., 19th & Lehigh, Philadelphia 32, Pa. . . . Manufacturers of Steam Power Plant Condensers • Vacuum Equipment • Marine Auxiliary Machinery • Water Supply, Drainage and Circulating Pumps.



HOW "REVERSE FLOW" WORKS

Left Side Shows Normal Operation

Water enters inlet A with right port open. Flows through tube bank C to rear of condenser . . . returns through tube bank D to front of condenser and discharges at E.

Right Side Shows Reverse Flow

Sluice gates move on a common stem. Water flows up through channel B, and through tube bank D to rear of condenser . . . returns through tube bank C to front of condenser.

In the C. H. Wheeler Divided Water Box Design, each half of the condenser can be back-flushed independently.

WE603

C.H. Wheeler OF PHILADELPHIA

J. R. P.
Here is an inexpensive, rugged forged steel valve that is quality-controlled to meet the highest standards
E. B. J.

ROCKWELL BUILT
Edward Valves

Large size knobbed handwheel eases operation.

Deep, full-size stuffing box and Evalpak packing combine to minimize maintenance.

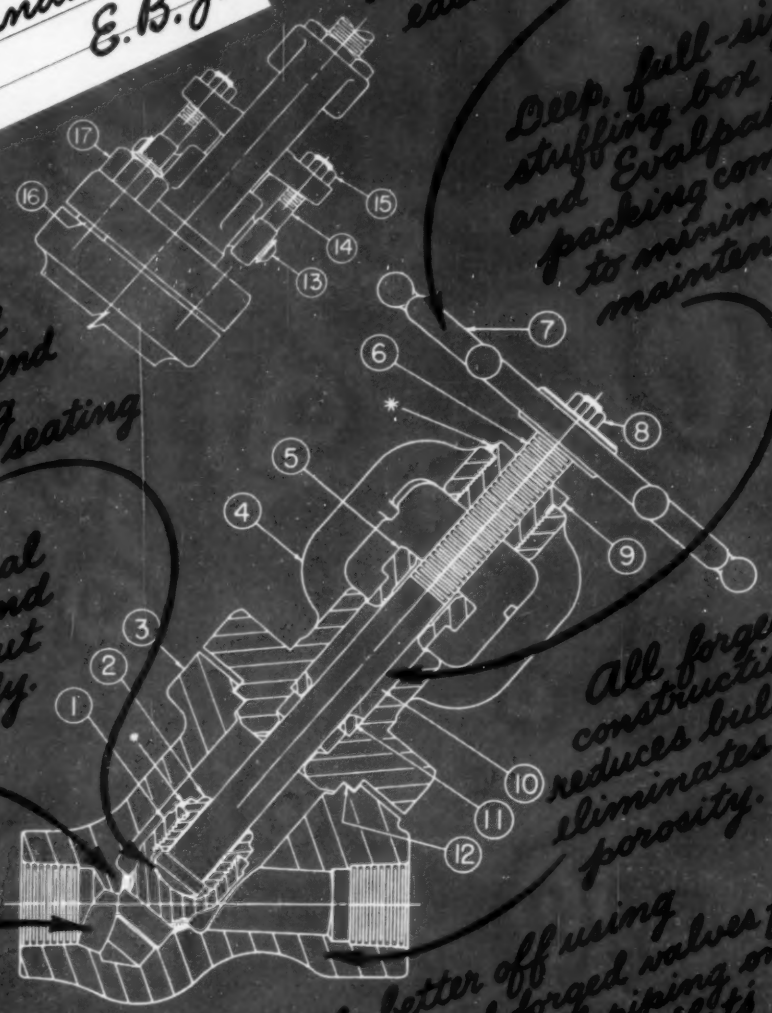
Swivel disk and radiused stem end prevent galling insure perfect seating

Edward integral Stellited seat and Stellited disk cut repairs sharply.

Straight through flow minimizes turbulance and pressure drop.

All forged construction reduces bulk-eliminates porosity.

We'll be better off using Edward forged valves for all small piping on our job. Let's get a bid.



LIST OF MATERIAL
QUANTITIES ARE FOR 1 GLOBE OR 1 ANGLE VALVE
WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

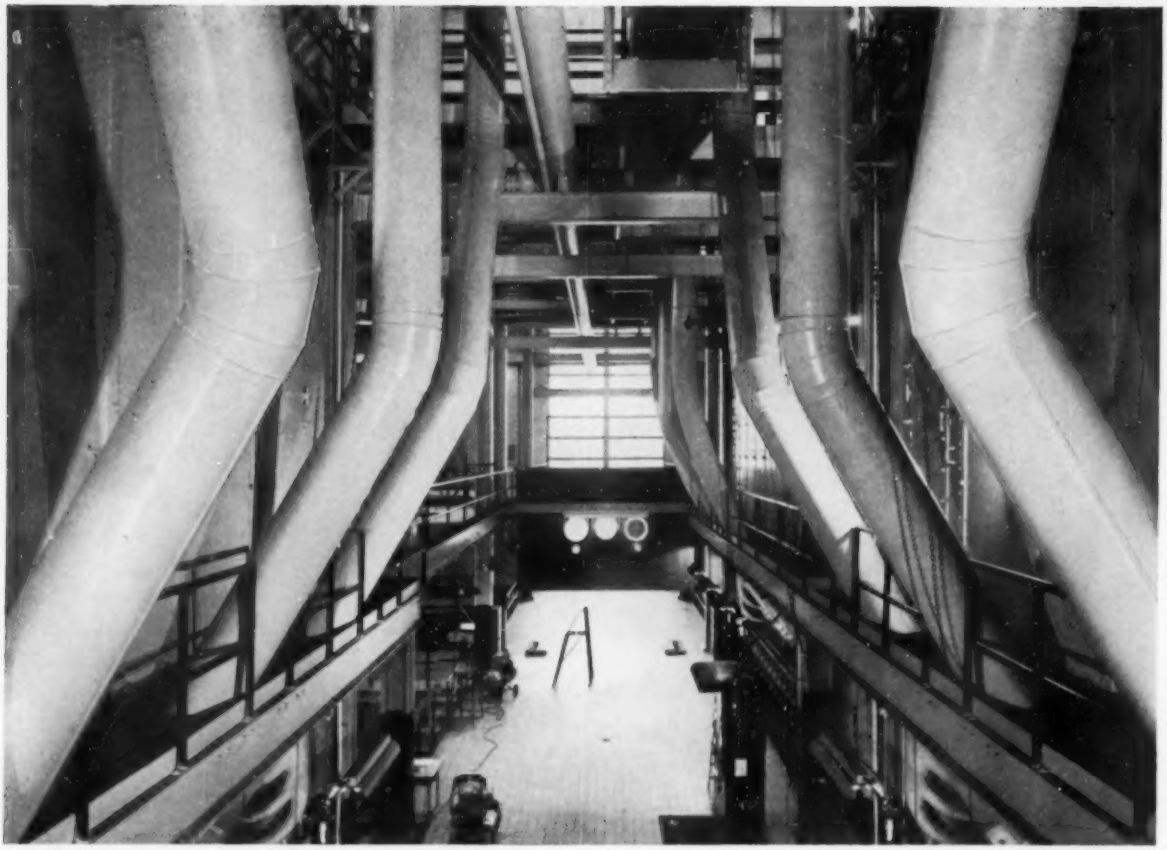
PIECE NO.	NAME OF PIECE	NO. REQ'D	MATERIAL	SPECIFICATIONS	EDWARD MS NO.
1	DISK	1	FORGED ALLOY	A.S.T.M. A182, GRADE F11	227
			STEEL STELLITED		483
2	DISK NUT	1	STEEL	A.I.S.I. C1120	123
3	BODY	1	FORGED STEEL (a)	A.S.T.M. A105, GRADE II	111 / 483
			FORGED STEEL (b)	A.S.T.M. A182, GRADE F11	227/483
4	BONNET	1	FORGED STEEL (a)	A.S.T.M. A105, GRADE II	111
			FORGED STEEL (b)	A.S.T.M. A182, GRADE F11	227
5	GLAND	1	MALLEABLE IRON	A.S.T.M.A220, GRADE 53004	324
6	STEM	1	EVALLOY	AISI GRADE 416	261
7	HANDWHEEL	1	MALLEABLE IRON	A.S.T.M.A47 GRADE 32510	322
8	STEM NUT	1	STEEL	A.S.T.M. A194 - GRADE 1	124
9	YOKE BUSHING	1	BRONZE	A.S.T.M. B62	412
10	PACKING RINGS		EVALPAK	HIGH TEMPERATURE PACKING	501
11	JUNK RING	1	STEEL-EVALIZED	A.I.S.I. C1120	123
12	BONNET GASKET	1	IRONKOTE		505
13	GLAND BOLT WASHER	2	STEEL		
14	GLAND BOLT	2	FORGED STEEL EVALIZED	A.S.T.M. A105, GRADE II	111
15	GLAND BOLT NUT	2	STEEL-EVALIZED	A.S.T.M.A194-GRADE 0	125
16	TAP END STUD	4	ALLOY STEEL (c)	A.S.T.M.A193	
17	BONNET STUD NUT	4	STEEL (c)	A.S.T.M.A194 -	

EDWARD VALVES, INC.
SUBSIDIARY OF ROCKWELL MANUFACTURING CO.
EAST CHICAGO, INDIANA

FORGED STEEL
GLOBE AND ANGLE VALVES

DRAWN		DRAWING NO
CHK'D		AE-3529-2
APP'D	DATE	

Edward builds Globe and Angle Stop, Non-Return, Check, Stop-Check, Gate, Blow-Off, Mudline, Relief, Hydraulic, Instrument, Gage, and Special Valves and Strainers.



Whether steam is your product or a part of your production process, uninterrupted coal flow is a must to maintain output. All chutes in the heating plant above, each 18" O.D., are of Lukens 3/16" 20% Type 304 stainless-clad steel to assure free coal flow.

G. S. A. Gets New Coal Chutes

FOR DEPENDABLE COAL FLOW—

LUKENS STAINLESS-CLAD STEEL

In its West Heating Plant in Washington, D.C., General Services Administration now depends on coal chutes of Lukens stainless-clad steel. Steam producing plants throughout the country are building and replacing with Lukens stainless-clad for these reasons:

ECONOMY—through greatly reduced maintenance cost in bunker noses, chutes, hoppers, pipes and spreaders.

EQUIPMENT LIFE—evidence of corrosion-free, trouble-free service matching the life of the boiler.

DEPENDABILITY—freedom from hangups and downtime that often result from wet coal.

PLUS—ready fabrication and design freedom to meet any plant requirement.

Get **Coal Handling Bulletin 740** for the performance facts and information you need to get the most from Lukens clad steel. Ask also for the names of some of the nation's best and most experienced coal handling equipment builders. Write to Manager, Marketing Service, 900 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

LUKENS ®

THIS IS LUKENS CLAD STEEL. Not a lining, not a soldered-on surface, but a solid steel plate—one side corrosion-resistant stainless steel, the other rugged, economical carbon steel. Their permanent metallurgical bond is produced by heat and pressure on the powerful rolling mills at Lukens.

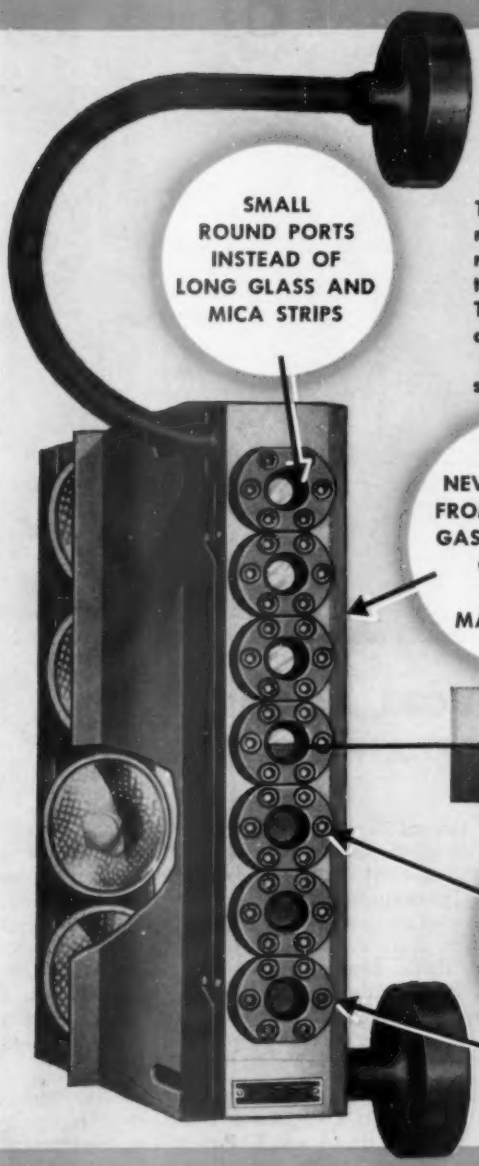
STAINLESS-CLAD STEELS FOR INTERIOR COAL HANDLING EQUIPMENT

Producers of the Widest Range of Types and Sizes of Clad Steel Plate Available Anywhere

MAKING Great Savings in GAUGE MAINTENANCE

(BOTH TIME AND COST)

DIAMOND "Multi-Port" BI-COLOR GAUGE


SMALL ROUND PORTS INSTEAD OF LONG GLASS AND MICA STRIPS
GAUGE NEVER REMOVED FROM BOILER FOR GASKET CHANGES OR OTHER NORMAL MAINTENANCE
STEAM SHOWS RED
WATER SHOWS GREEN
COMPLETE PORT CHANGE REQUIRES ONLY ABOUT 15 MINUTES
EACH PORT THERMALLY INDEPENDENT

The Diamond "Multi-Port" Bi-Color Gauge makes startling reductions in maintenance costs. In cases where accurate records have been kept, labor and material costs are less than 1/5 the maintenance of conventional open port gauges. This is due to the unique design . . . note particularly the advantages that are pointed out on the photograph.

The "Multi-Port" operates on the Bi-Color principle . . . steam always shows red . . . water always shows green. There can be no question of water level. The gauge has been in continuous successful high pressure operation for more than three years in leading central station plants. Users report excellent readability and exceptionally high availability as well as important reductions in maintenance. Return the coupon below to get a copy of Bulletin 1174.

7320

DIAMOND POWER SPECIALTY CORP.
LANCASTER, OHIO
Diamond Specialty Limited — Windsor, Ontario

DIAMOND POWER SPECIALTY CORP. V
LANCASTER, OHIO

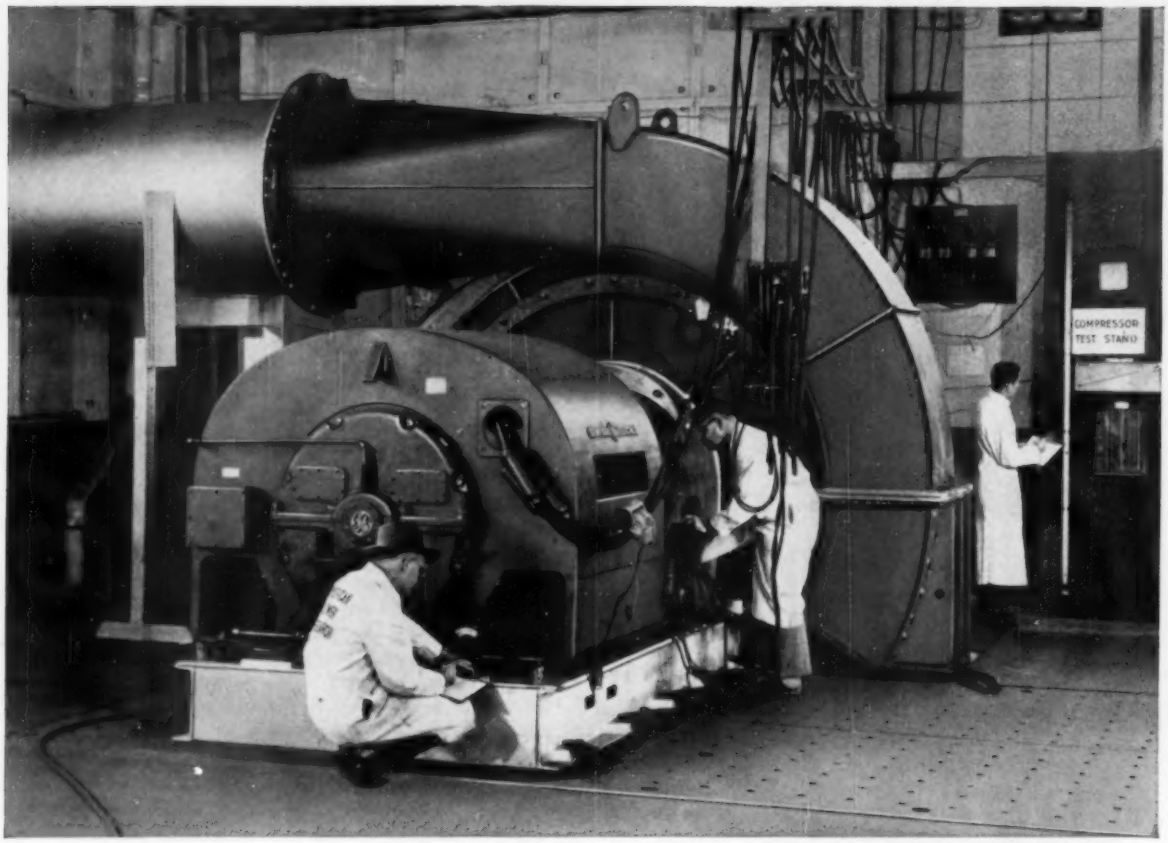
Please send me without obligation a copy of new Bulletin No. 1174 explaining the advantages of the Diamond "MULTI-PORT" Bi-Color Gauge.

NAME_____

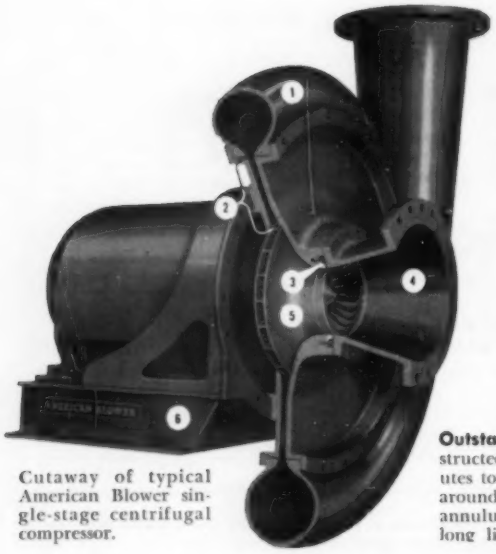
COMPANY_____

ADDRESS_____

Here's the latest air-handling



LABORATORY TESTED CENTRIFUGAL COMPRESSOR DELIVERS 330,805 POUNDS OF AIR PER HOUR!



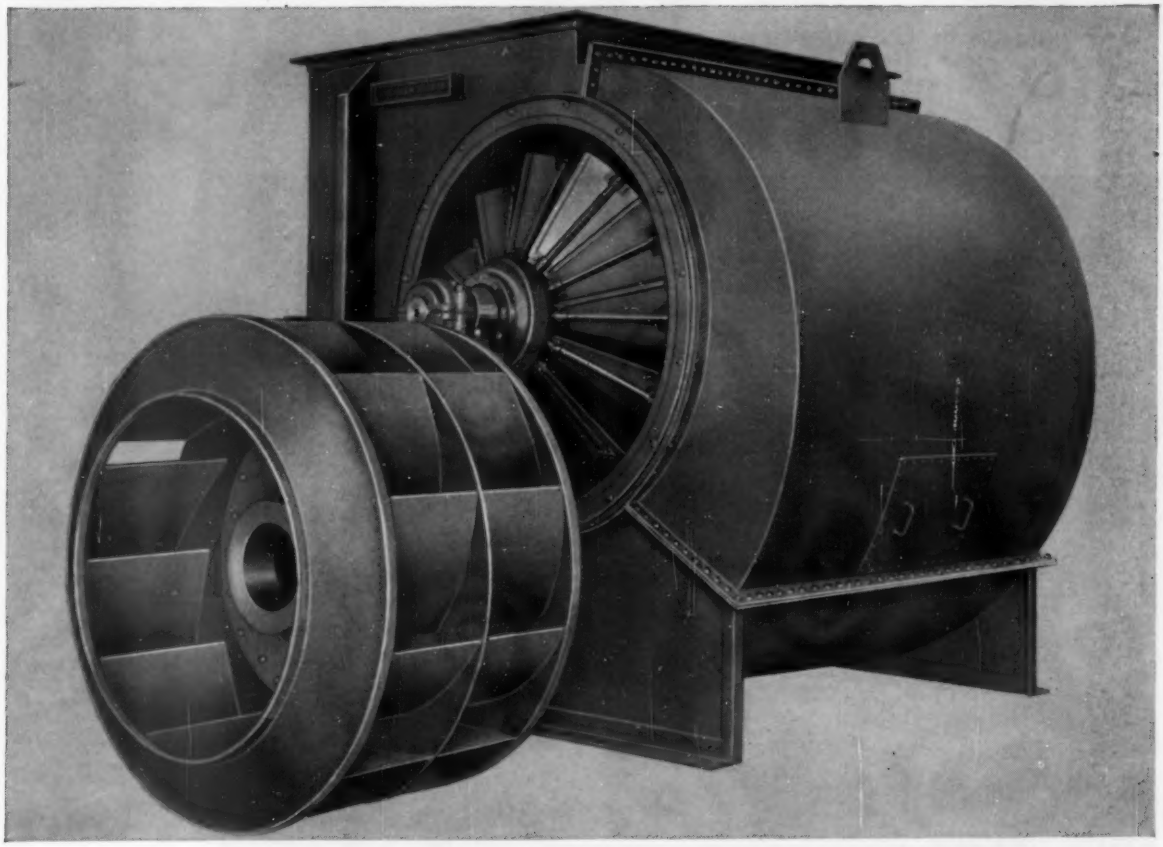
Cutaway of typical American Blower single-stage centrifugal compressor.

With the trend toward higher pressure requirements, American Blower has designed and built centrifugal compressors to furnish air for cyclone fired boilers. These compressors incorporate the use of a horizontally split, welded steel volute casing, variable inlet guide vanes, welded steel impeller of the shrouded type with impeller shaft supported by two journal bearings plus a Kingsbury thrust bearing arranged for positive forced-feed lubrication. This highly efficient compressor is driven by a 1000 HP, 1800 rpm, induction motor, delivers 330,805 pounds of air per hour at a static discharge pressure of 67.5 inches water gauge.

Like every American Blower single-stage centrifugal compressor – 30 to 2250 HP – this compressor has been completely tested in accordance with the A.S.M.E. Power Test Code. Such testing guarantees the mechanical operation and performance of all American Blower compressors.

Outstanding features: (1) Improved scroll-shaped casing design. (2) Unobstructed long diffuser passage converts velocity energy into pressure, contributes to quiet operation. (3) Annulus packing minimizes recirculation of gas around impeller inlet. (4) Removable inlet nozzle for accurate alignment of annulus packing. (5) Aero-dynamic design of impeller blades for high efficiency, long life. (6) Welded-steel baseplate "stress relieved" prior to machining.

equipment from American Blower

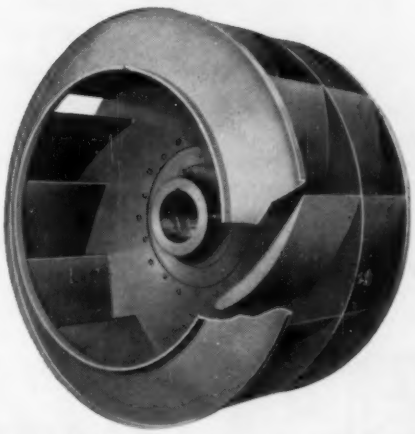


AIRFOIL FAN HAS ADVANCED DESIGN FOR HIGH EFFICIENCY, LOW OPERATING COST

Featuring a functionally designed airfoil blade, American Blower's improved Airfoil Fan is the industry's best in the non-overloading-horsepower type of centrifugal fan.

That's because smooth interworking of improved streamline inlets, wheel rims, and housing minimizes turbulence, resulting in higher efficiency, lower power consumption. The non-overloading-horsepower characteristic makes it possible to select a driving motor close to the fan horsepower.

Why not talk to an American Blower sales engineer about *your* requirements. His knowledge of air-handling applications can prove invaluable to you. Call our nearest branch office, or write: American Blower Division of American-Standard, Detroit 32, Michigan. In Canada: Canadian Sirocco products.

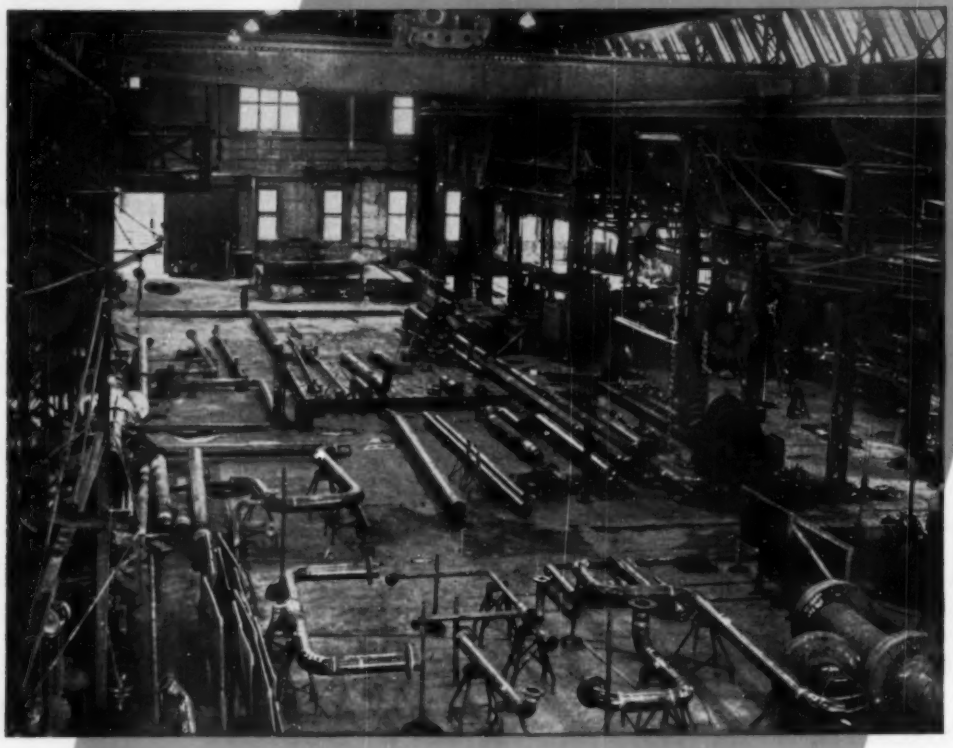


Special design of the airfoil blade and matching streamline inlet are the top features of American Blower Airfoil Fan. The dieformed, reinforced, and welded blades are extra strong, extremely efficient. Single- and double-inlet Airfoil Fans are available in many sizes, and for volumes up to 1,000,000 cfm.

AMERICAN BLOWER

Division of AMERICAN-Standard

"STOP the work!
... Advertising wants a picture"



This central-section view of our Main Shop is partial evidence of facilities which, though complete in plant and field, are overshadowed by an intangible reason for your interest. Namely, our 58 years' specialized experience in prefabricating and installing high-temperature, high-pressure piping. On your next job . . . ask us in.

WESTPORT JOINT
(PATENTED)

W. K. MITCHELL & CO., INC.
Philadelphia 46, Pa.

MITCHELL PIPING
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

THIS IS BAILEY ARMORTUBE CABLE

every foot you install saves you $5 to $6

ARMORTUBE Cable consists of multiple copper or aluminum tubes in a single, flexible armored cable. You string *one* line. You buy *one* set of standard pipe supports or conduit clips. You make a neater, protected installation. Installation costs are reduced tremendously.

Users of copper or aluminum tubing for connecting pneumatic instrument and control lines report that it costs about $2.00 a foot to install single tubes.

It costs the same $2.00 a foot to install Bailey ARMORTUBE Cable.

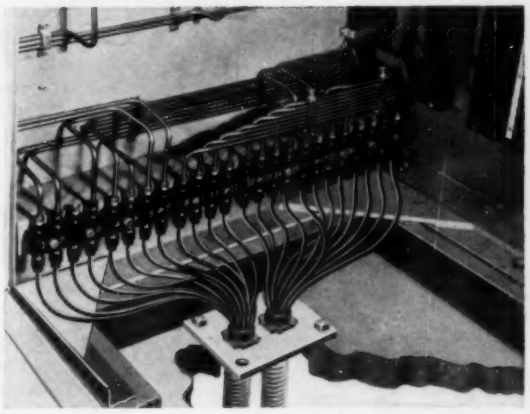
But here's what customers tell us . . .

SAVES $3,000—A chemical plant bought 530 feet of 4-tube Bailey ARMORTUBE Cable and installed it at a saving of $3,000 over the cost of four single tubes.

SAVES $14,000—Another chemical plant bought ARMORTUBE Cable costing $1,345. The saving on installation compared to single tubes amounted to $14,000.

SAVES $60,000—An electric utility bought $14,068 worth of ARMORTUBE Cable . . . saved $60,000 on installation.

Whether your next job consists of 100 or 100,000 feet of tubing, it will surely pay you to check on savings possible with Bailey ARMORTUBE Cable. For more information ask for Product Specification and Price List G91-9.



NOW—to meet increasing demands, this cost-saving product is offered in a full family of sizes and types. In the quarter-inch tube size, ARMORTUBE is available in both copper and aluminum with 2, 3, 4, 5, 7, 8, 10, 12 or 19 tubes. Tubes are protected with galvanized steel armor or a combination of steel armor and thermoplastic . . . with thermoplastic sheath located either over or under the steel. Other sizes are copper tubes in steel armor only: 3/8" in bundles of 1, 2, 3, 4, 7; 1/2" in bundles of 1, 2, 3, 4. G-38

Instruments and controls for power and process

BAILEY METER COMPANY

1025 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

Station Load changes from 100% to 12%

...ON AUTOMATIC CONTROL

Hagan Automatic Systems help keep Niagara Mohawk Albany Station on frequency control

A new station seldom encounters as drastic load changes as Niagara Mohawk's Albany Station. At the end of a chain of water power stations, it has the job of taking up the slack as water level and power demand varies. During the spring season, it may swing from 50 MW at night to its maximum rated output of 400 MW during the day. No matter how low the load falls, the station stays on automatic.

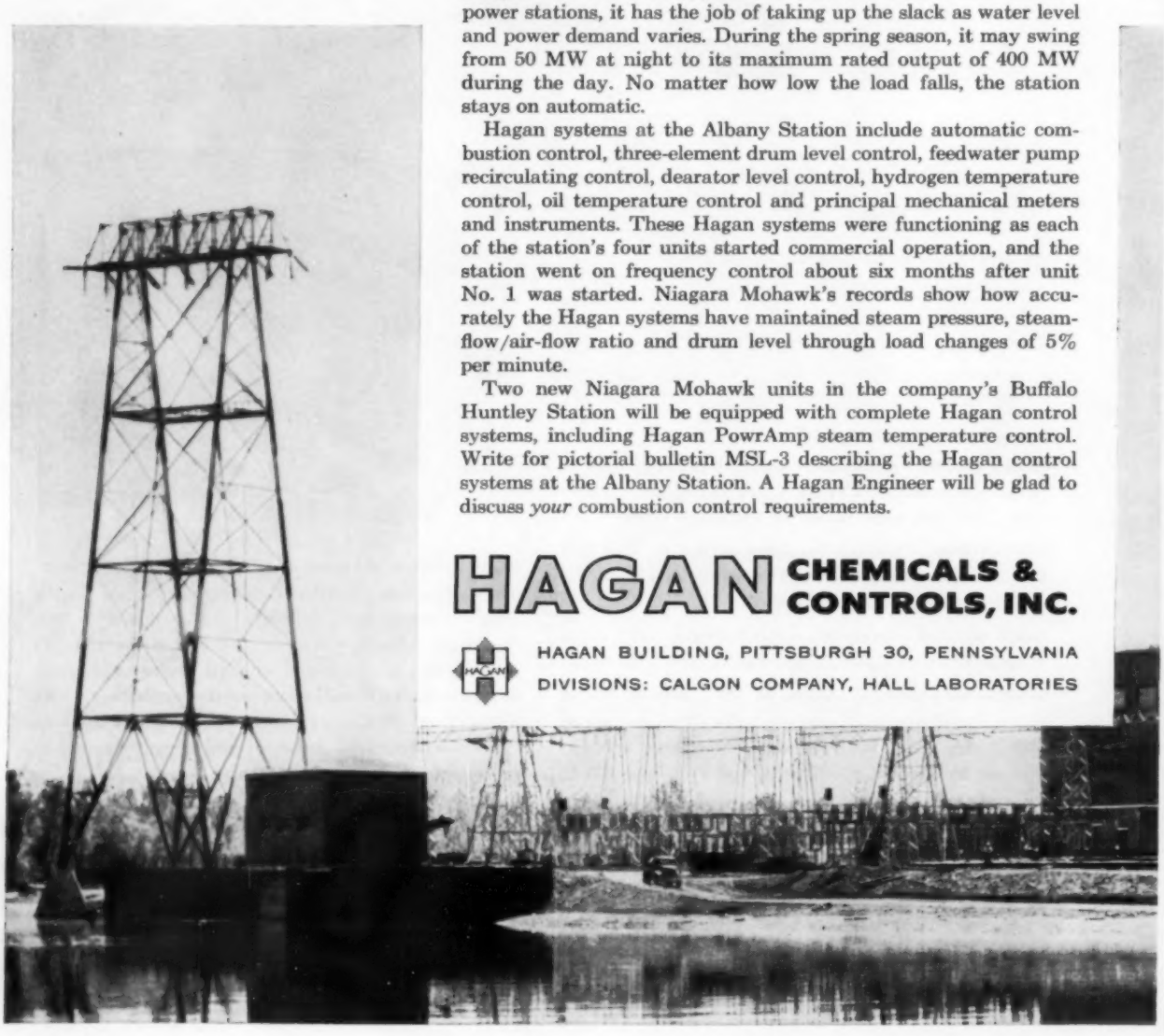
Hagan systems at the Albany Station include automatic combustion control, three-element drum level control, feedwater pump recirculating control, dearator level control, hydrogen temperature control, oil temperature control and principal mechanical meters and instruments. These Hagan systems were functioning as each of the station's four units started commercial operation, and the station went on frequency control about six months after unit No. 1 was started. Niagara Mohawk's records show how accurately the Hagan systems have maintained steam pressure, steam-flow/air-flow ratio and drum level through load changes of 5% per minute.

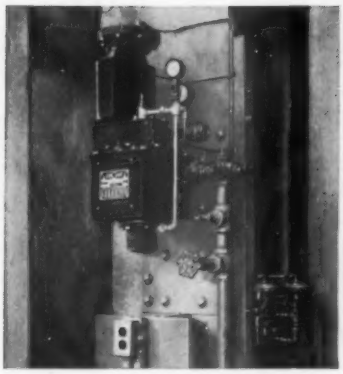
Two new Niagara Mohawk units in the company's Buffalo Huntley Station will be equipped with complete Hagan control systems, including Hagan PowrAmp steam temperature control. Write for pictorial bulletin MSL-3 describing the Hagan control systems at the Albany Station. A Hagan Engineer will be glad to discuss *your* combustion control requirements.

HAGAN CHEMICALS & CONTROLS, INC.

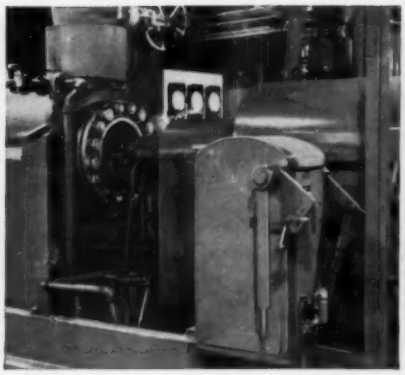
HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA

DIVISIONS: CALGON COMPANY, HALL LABORATORIES

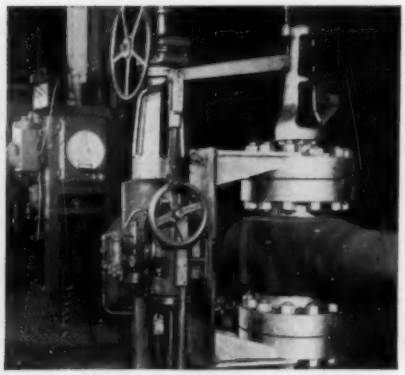




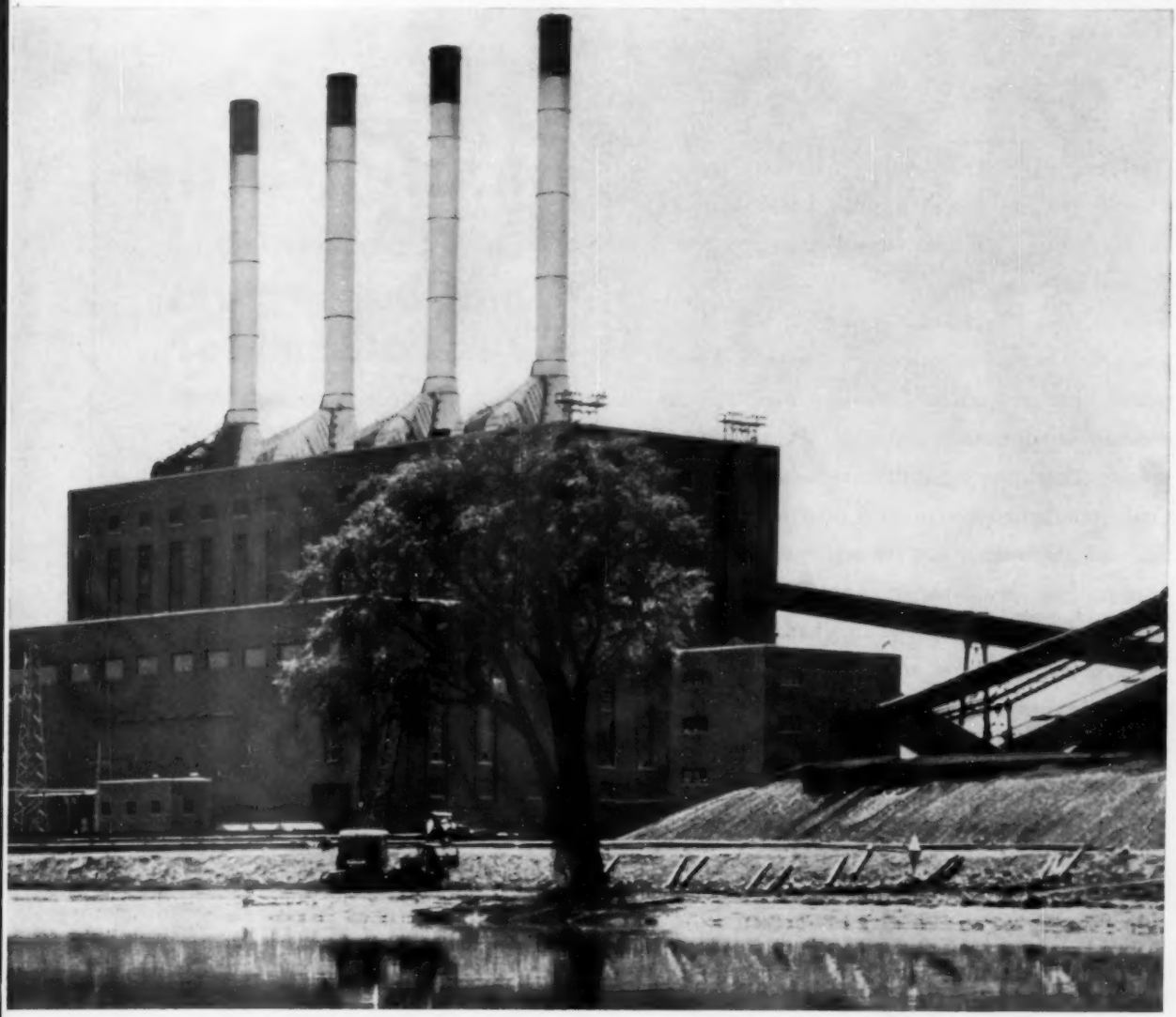
Hagan Furnace Pressure Regulator. This installation is equipped with the Hagan remote switching system, eliminating the lag normally present in long-line pneumatic systems. Controlling the Forced Draft Fan inlets, this Hagan Regulator is a unique instrument. Instant response, high stability and wide range adjustment makes the Hagan Regulator easy to tailor to a specific application.

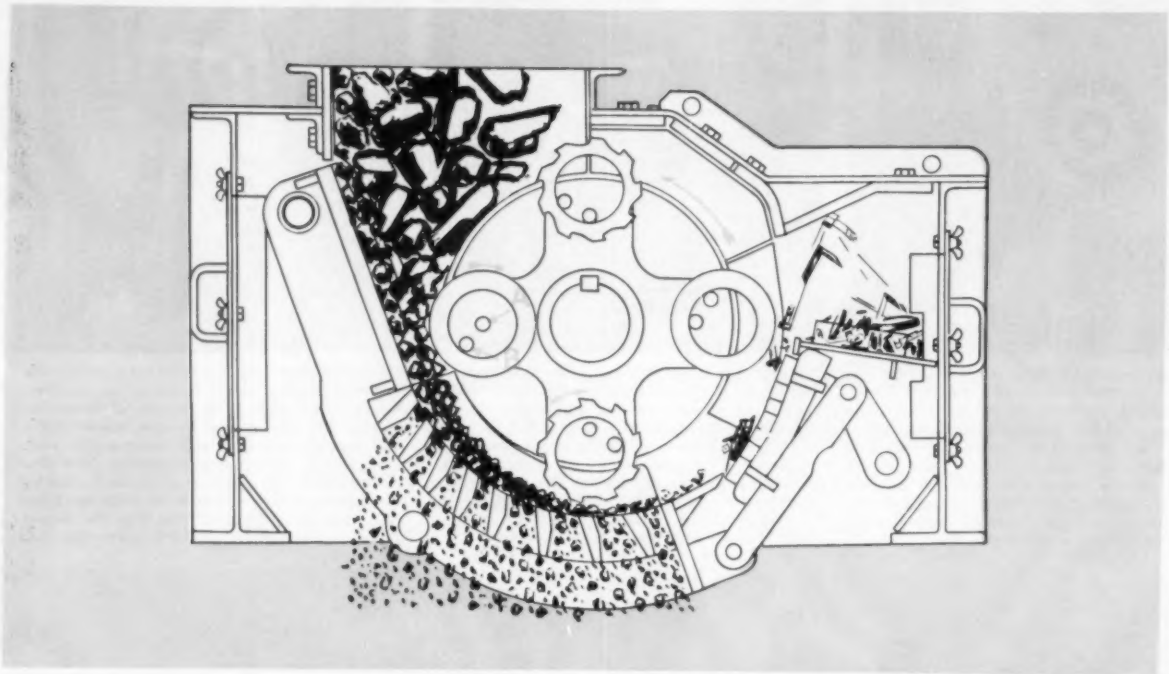


Boiler Feed Pump Hydraulic Coupling Control, Here a 6 x 10 Hagan Power Positioner implements the signal from the feed water control. This Power Positioner is one of a full range of sizes suitable for many positioning applications. Hagan Power Positioners are fast and accurate, with dependable repeatability. The panel in the background contains Hagan Ring Balance meters which record the three separate flows, totalize each flow and record the total of all three.



This 5 x 10 Hagan Power Positioner positions the feedwater control valve. Normally on standby, this valve is an alternate means of feedwater control. The Hagan Ring Balance Meter in the background transmits boiler drum water level, compensated for changes in density. This provides reliable and accurate drum level reading from atmospheric pressure to full operating pressure when going on or off the line. For details on this unique system, ask for Bulletin MSA-117.





This original Pennsylvania crushing action, whereby snubbed down rings* roll slowly across the feed with a constant intense pressure, cracks the coal into uniform granular pieces with a *minimum of fines.* The Pennsylvania Coal Granulator produces a premium product that protects against stoker and pulverizer overload, loss of fuel through overgrinding and coal segregation on stokers. That's the big difference in these proven Coal Granulators—the product they produce. And after all, that's what you are really buying in the long run, not just capacity, but specified capacity of a product that's superior to what other crushers produce. To learn more about the features that set Pennsylvania Coal Granulators way out ahead, send for bulletin 9003. And remember, the greatest developments in crusher design are still coming from Pennsylvania!

* see A and B in above illustration.

PENNSYLVANIA CRUSHER DIVISION
Bath Iron Works Corporation
West Chester, Penna.

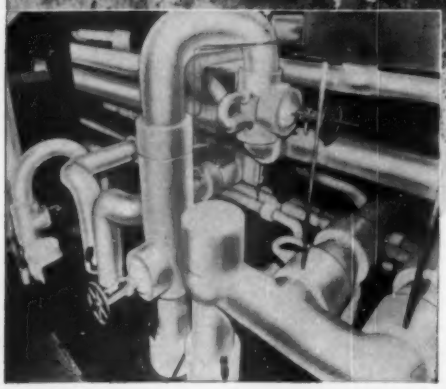
GRANULATION
the economical method of coal reduction for Stokers and Pulverizers
•
MUCH LESS OVERGRINDING

PENNSYLVANIA

COAL GRANULATORS

PE-249

Harness the Energy of Steam with *Pittsburgh Piping*



Pittsburgh Piping installation of high pressure boiler feed piping in central station.

Are you interested in piping to harness the flow of superheated steam, gas or liquid, or to control the corrosive action of process materials?

Call upon Pittsburgh Piping for this type of piping . . . for the electric generating station, nuclear power installation, chemical processing plant, refinery, mill, or factory.

We are specialists with complete facilities, and we assume responsibility for every phase of a piping job — from blueprint through erection.

Pittsburgh Piping

AND EQUIPMENT COMPANY

158 49th Street — Pittsburgh, Penna.

CANADA: CANADIAN PITTSBURGH PIPING, LTD. 835 BEACH ROAD—HAMILTON, ONTARIO

PP-25

PRODUCTS AND SERVICES

Carbon Steel Piping	Forged Piping Materials
Cast Iron Fittings	Headers
Cast Steel Fittings	Manifolds
Chrome-Moly Piping	Pipe Bends
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1938	Essex (Newark)	25 and 26	4	520,000
1940	Burlington	12 and 13	2	448,000
1941	Marion (Jersey City)	51 and 52	2	448,000
1942	Burlington	14 and 15	2	448,000
1946	Kearny	1 (Mercury Blr.)	1	160,000
1947	Essex (Newark)	1	3	380,000
1955	Burlington	7	2*	600,000
		Total	17	3,274,000

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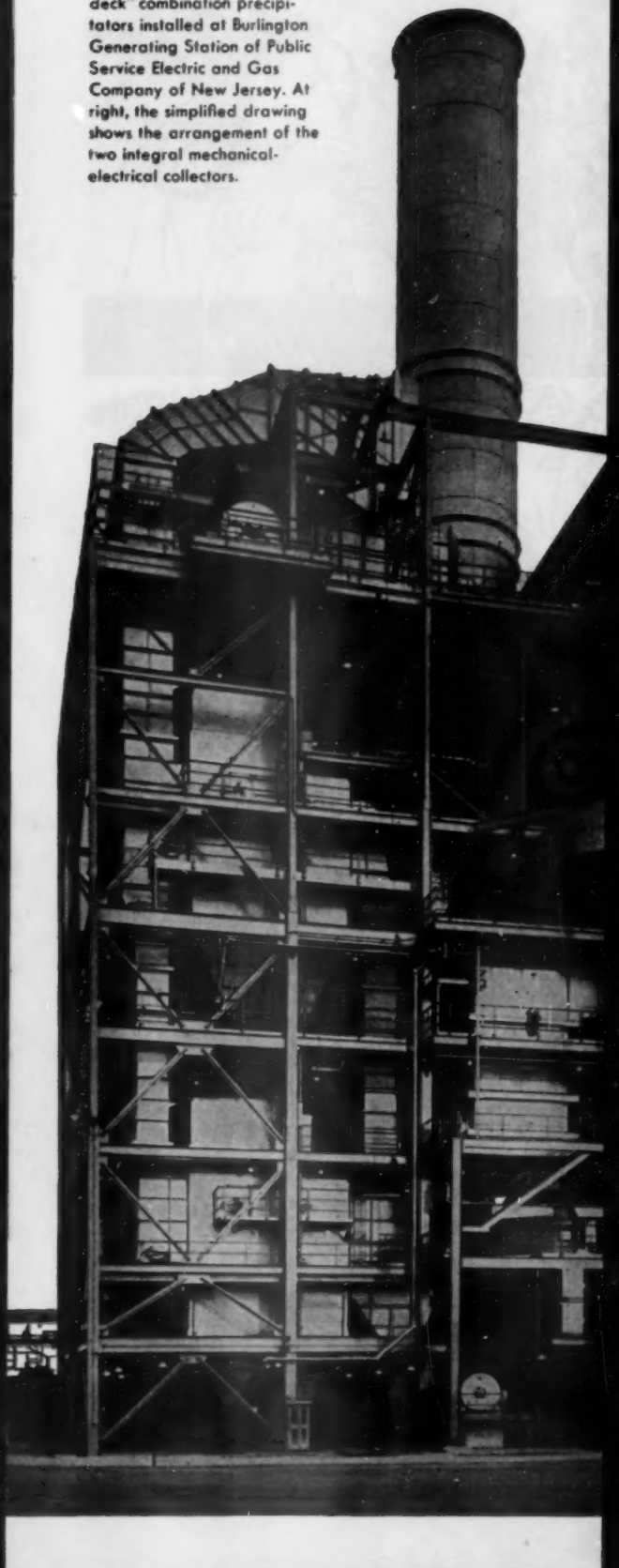
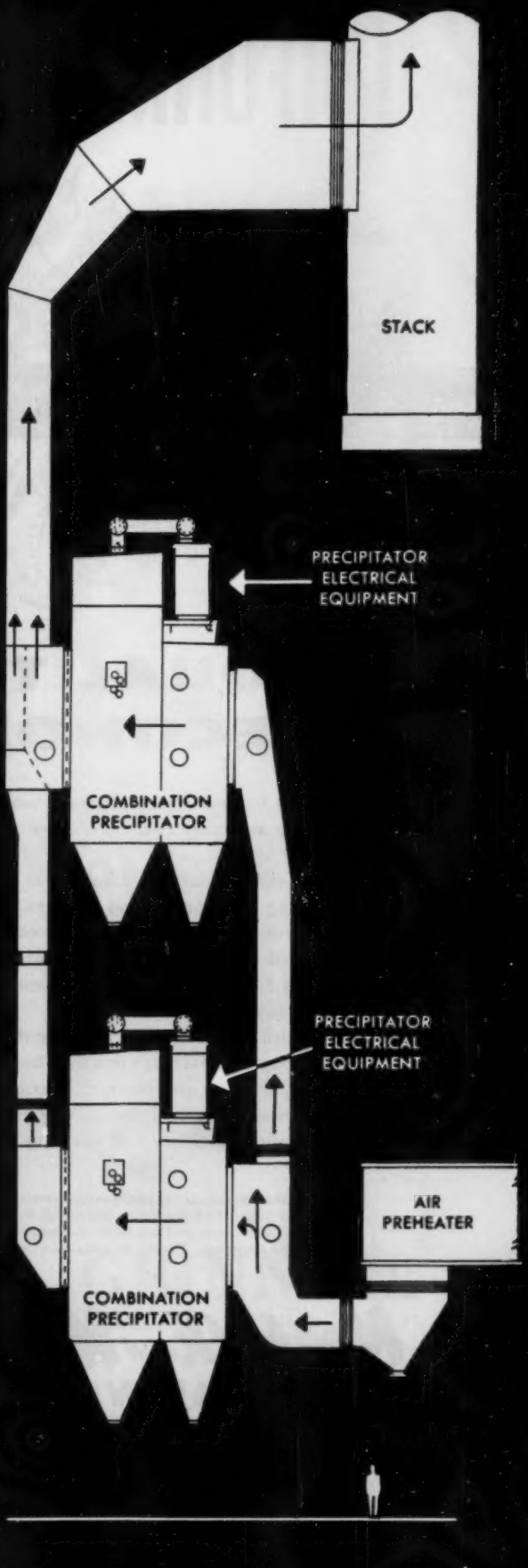
Research-Cottrell's "double-deck" combination precipitators installed at Burlington Generating Station of Public Service Electric and Gas Company of New Jersey. At right, the simplified drawing shows the arrangement of the two integral mechanical-electrical collectors.





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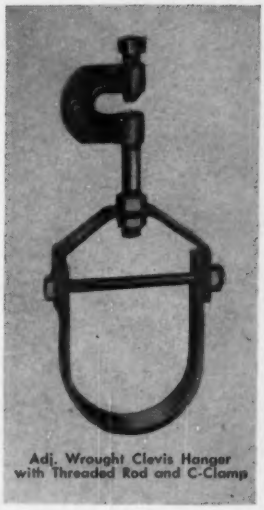
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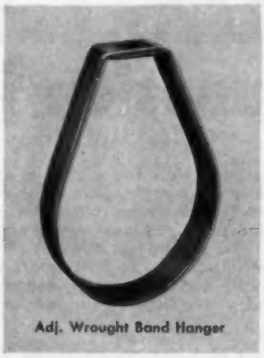
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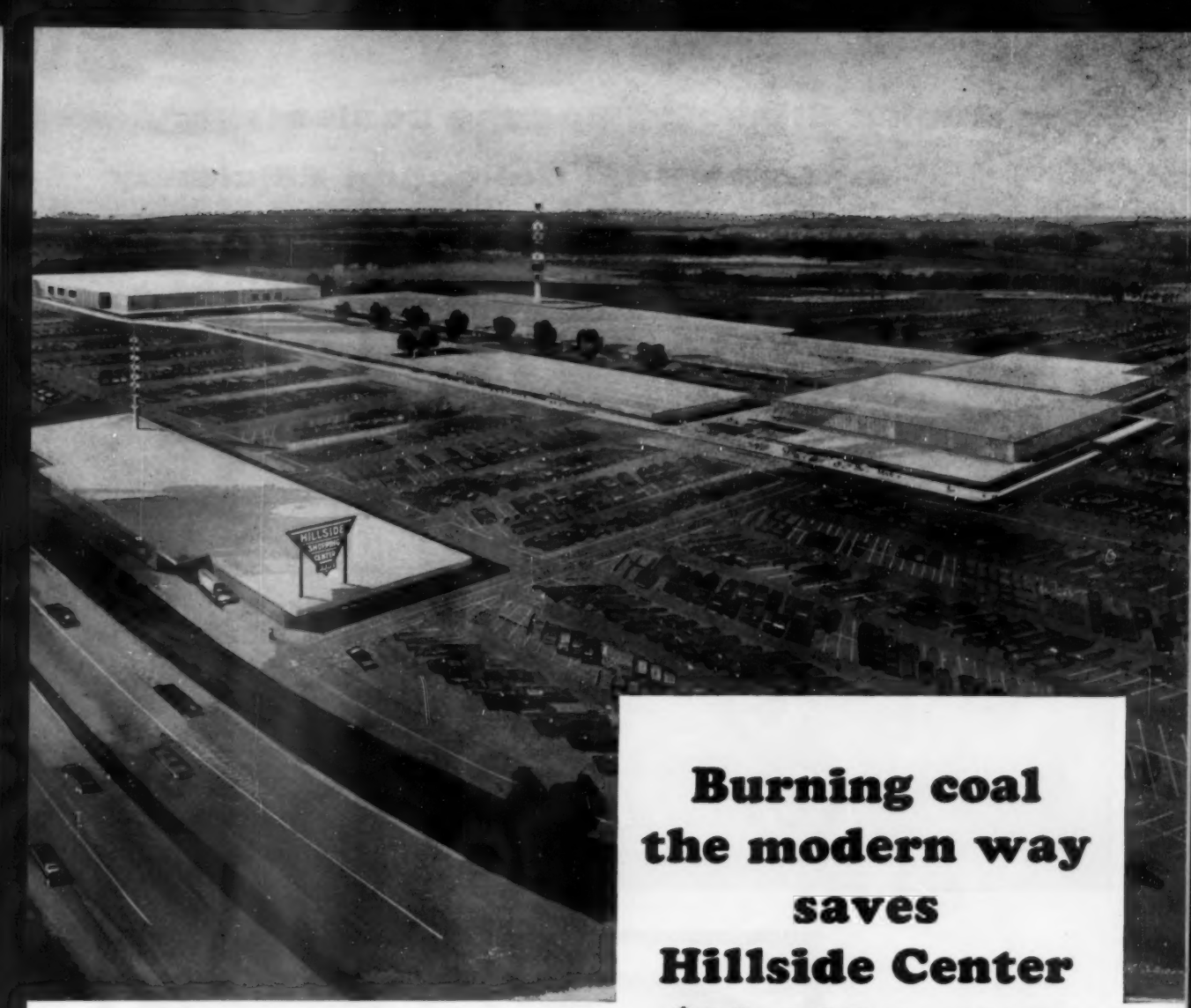

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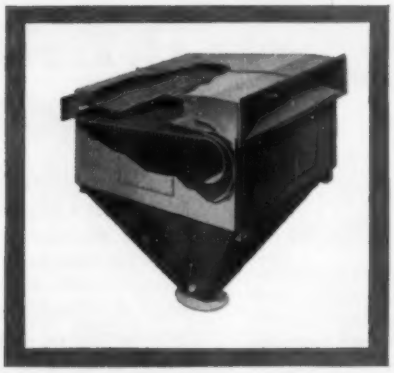

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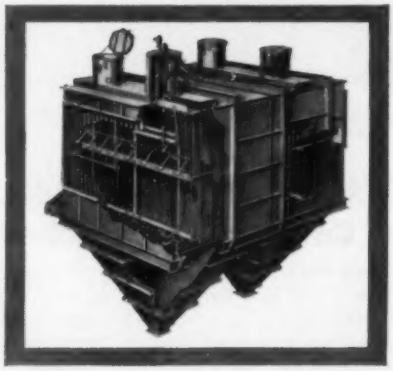

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Editorial

National Science Youth Day

The 110th anniversary of Thomas Alva Edison's birthday, February 11, just celebrated by the electrical industry in the U. S., took on added significance with the designation of this same date by the Celebration Committee as National Science Youth Day. Efforts were and are being made toward dramatizing the achievements of Edison in the general field of science with especial emphasis on appealing to the high school youth. We think this is a recognition of the proper area to attempt stimulation of more recruits to engineering and science.

In this issue on p. 61 we have published the comments of an associate professor of history at MIT, John B. Rae, on the subject of the engineer and the American economy. We recommend it highly. Mr. Rae says in part "Some of the proposals (to attract more engineers) make sense—revamping our educational system to put more emphasis on mathematics and science and to direct more of our talented youth into technology. Some border on the hysterical, like the school of thought which advocates that engineers can be restricted to purely technical functions and not allowed to fritter away their skills in such areas as management." An excellent summation, we think, of the situation.

Our contemporary, *Engineering*, an eminent British publication, reported a major debate in the House of Lords the latter part of November on, as one spokesman put it, "the almost desperate urgency of this nation's requirements for more engineers." In advancing this viewpoint the British Ministry of Labor's recent "Report on Scientific and Engineering Manpower" was cited. This indicated present totals of 56,000 scientists and 78,000 engineers equivalent to 0.6 per cent of the population, now employed in Britain. As a matter of comparison Russia was thought to have 0.85 per cent and the U.S.A. 1.2 per cent, respectively, of their working populations similarly engaged. Unquestionably these ratios carry significance and the approach employed by Russia to raise the ratio in its own country is, by all reports, remarkable. Yet that approach, as others have pointed out, is not necessarily the only or, for our country, the right one.

The electrical industry's decision to inspire or to excite the imagination of our youth to the rewards and the satisfactions a technical occupation can offer is a sound decision and one in keeping with our free enterpise system. From an educational standpoint engineering organizations as well as the individuals in it should guarantee our youth that the school facilities will be there to assist and to further their technical ambitions. Until such an approach, attuned to our national heritage has been tried and found wanting we feel any stronger, more dictatorial avenue will develop barriers of opposition against the method and produce adverse results.

Recognition of Engineering Specialties

If one were to search for a good example to explain the nature of geometric progression, he might cite the structure of the engineering profession. In antiquity miliary engineering was the only specialty in existence. Later there became two forms, civilian and military. At that point the progression had started (1 + 2 + 4 + 8 + 16 . . .) and today there are several hundred engineering specialties and an almost proportionate number of technical societies to represent them.

This proliferation of specialties and societies is understandable when one considers the scope and growth of technology and the innate desire of individuals sharing common interests to band together in some form of organization. But there are dangers in allowing this process, which is still an accelerating one, to go too far. Communication between different types of specialists breaks down, common intellectual ties may be lost sight of, and engineers having broader interests become burdened with memberships in many organizations which may overlap and duplicate one another's efforts.

Engineers Joint Council is an agency that has recognized this problem and is doing something about it. Back in September, 1953, EJC established a committee under the title of "Recognition of Specialties in Engineering." Among its other accomplishments this committee acted as a catalyst in getting EJC and its constituent societies to coordinate the highly successful Nuclear Engineering and Science Congress held in Cleveland in December, 1955, an activity which is being continued in the 1957 Nuclear Congress scheduled for Philadelphia on March 11–15. This Committee has also cooperated in the formation of the American Sanitary Engineering Intersociety Board in which the American Society of Civil Engineers, the American Water Works Association and the American Society for Engineering Education are participating. Currently the Committee on Recognition of Specialties in Engineering is studying the questions of some sort of society structure for specialists concerned with hydraulics involving oil-type controls.

As the 1956 EJC Annual Report states, "Many splinter groups have been formally organized into a horizontal structure without regard to the EJC professional societies which might be considered as vertical segmentations of engineers into professional categories." New specialties will continually be created, but there is little reason for each one to have its own separate technical society when an organizational structure already exists that can service those interested in the specialty. Efforts by EJC to find means for newly created specialties to be encompassed within existing societies, whenever this is possible, deserve strong support from the entire engineering profession.

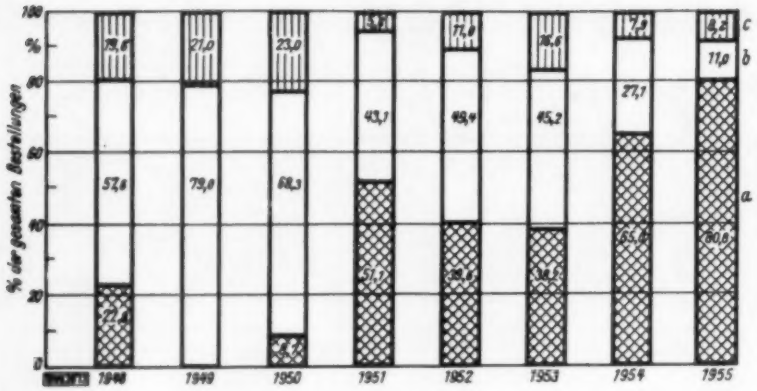


Fig. 1—Proportion of units with slagging furnaces compared to total steam generator capacity above 130,000 lb per hr

State of Slagging Furnace Development in Germany*

Slagging furnaces considerably reduce the difficulties and costs of removing combustion residues in dust form. This article presents some of the reasons for the extensive use of wet bottom fuel firing in West Germany including a detailed review of the present state of development, together with a description of the different designs currently in use. The field of application of slagging furnaces is outlined as well as means to burn coals with ashes having very high fusion temperatures.

By P. GRASME

Allgemeine Elektrizitätsgesellschaft†

DURING the last few years steam generating units with slagging furnaces have been increasingly popular in West Germany. Their share of all steam generators with capacities of more than 130,000 lb per hour ordered between 1948 and 1955 for operation in West Germany is shown in Fig. 1. This does not include the numerous older boilers which have been rebuilt with slagging furnaces. Of 65 such large units ordered in 1954, 58 employed slagging furnaces.

Slagging furnaces are principally used for firing bituminous coals. A few units with slagging furnaces for raw brown coal which has lower rank than lignite have also been successfully and continuously operated for a number of years.

The extensive use of wet bottom operation stems from the continuously increasing difficulties and costs accompanying the transport and disposal of the fly ash from power plants using bituminous coals in dry bottom units. The problem has become more acute because all residual fuel from mining operations is now being fired in power plants. Most mine mouth plants and utilities located nearby use bituminous coals with an as-fired ash content of 20 to 30 per cent and some above 40 per cent.

The tremendous ash quantities continuously being produced as fly ash by such fuels fired in dry bottom units became impracticable to dispose, especially since few useful applications of this ash have been developed.

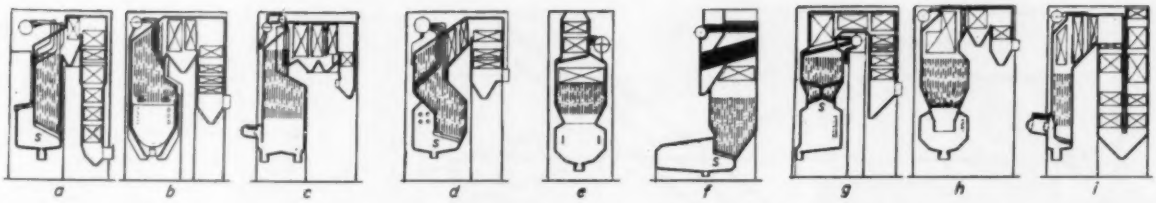
Furnaces with wet bottoms avoid these difficulties because they produce all combustion residues in a granulated, hard form without accompanying dust. In this manner the slag can be used almost anywhere for road building, as an additive for cement in the building industry, or at least as filling for mines or open tracts. It can be transported without dust nuisance and, due to its higher density, with less volume than fly ash.

In addition, slagging furnaces offer the advantage of operating with lower excess air and therefore with lower exit gas losses than other types of furnaces. Wet bottom units show a very flat efficiency characteristic between full load and half load which offers an economic advantage for power plants with wide load fluctuations.

Despite the low excess air ratio, unburned carbon can readily be avoided. Moreover, under proper operating

* Paper 205 G2/12, presented at the 15th World Power Conference, Vienna, 1956, and published in the German magazine, *BWK*, Vol. 8, Number 6, June 1956.

† Heat Engineering Department, Berlin—Grunewald.



a Closed furnace with vertical burners, U-flame and slag screen (*S*)
b Open furnace with slagging hopper and tangential burners.
c Open furnace with slagging table and tangential burners
d Closed furnace with opposing horizontal burners and slag screen (*S*)
e Open furnace with waistline and tangential burners
f Closed furnace with slagging hearth, vertical burners and slag screen (*S*)
g Closed furnace with tangential burners and slag screen (*S*)
h Vertical cyclone furnace
i Horizontal cyclone furnace

Fig. 2—Slagging furnace designs represent wide interest in this firing method over a long period of years

conditions fuels with a high sulfur content have not shown any SO_3 in the stack gases thus allowing the dew point to remain practically as low as the moisture content would indicate. The use of exit gas temperatures lower than with other types of firing can therefore be justified for such conditions.

The residue from slagging furnaces has a glassy appearance, includes no water-soluble substances, and only occasionally contains traces of unburnt carbon. The water required for granulating and hydraulically moving the slag remains practically free of suspended matter and will not be polluted by salts or acids. This is of considerable importance where water supply is short and recirculation desirable.

At present slagging furnaces in Germany burn bituminous coals with 8 to 40 per cent volatile matter and from 5 to more than 40 per cent ash content (8, 23).[1] Their use has been proved in continuous operation for most of the German bituminous coals with the exception of those with a very high fluid ash temperature. Recently it has been possible to fire even such coals in slagging furnaces by moderate addition of lime.

Present State of Development

All designs utilize completely water-cooled furnace walls usually employing natural circulation. In some cases forced circulation of feedwater has been used for individual smaller sections. The tubes are spaced sufficiently close to have the opening between them covered by commonly used studs and refractory. Some designs use tangent tubes. The machine welded studs hold and cool the refractory which is applied after erection for sealing and smoothing the inside surface of the slagging furnace.

Other common characteristics are high secondary air temperatures of above 750 F and combustion with very low excess air. The units are operated with a CO_2 content of 16 to 17 per cent ahead of the airheater.

Spill-over slag pools are no longer used. In all current designs the slag leaves the furnace continuously through bottom openings into a water tank. The bottom is designed to keep the slag moving toward the opening from all sides and to have it leave in one concentrated stream.

The various designs attempt to concentrate combustion and slag-melting within the refractory-covered slagging furnace. Immediately following this, the gas temperature is reduced by slag screens and by radiant furnaces with closely spaced wall-tubing comprising evaporator and superheater radiant surface.

Depending on the coal quality, injection of the pulverized coal into the slagging furnace is direct or by storage system. The latter is preferred with coals having high moisture or low volatile content. The storage system is also generally used with the horizontal cyclone furnaces which are operated with an especially low air ratio of 1.07 to 1.10. Very slight variations of the coal-air ratio in the furnace are thereby avoided.

The overall power consumption of units with slagging furnaces is approximately equal or only slightly higher than for dry bottom units. Dimensions are also comparable (11, 26).

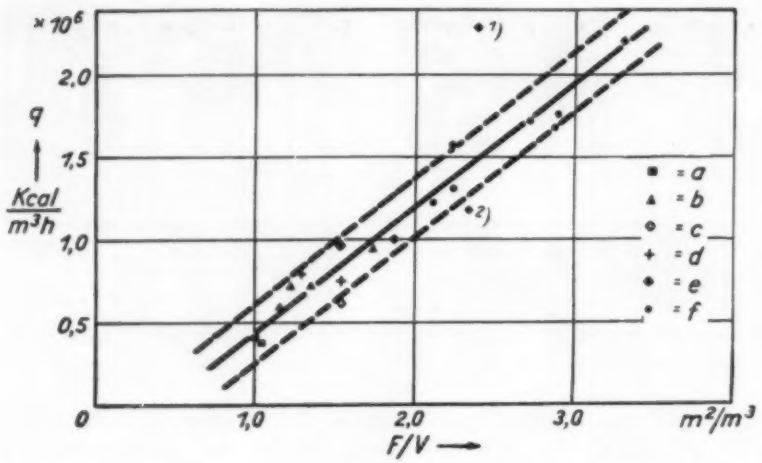
Main Types of Design

Aside from these common characteristics, the slagging furnaces show a wide variety of designs and many basic differences. This indicates that development efforts are still in progress.

Starting with the large and high furnaces associated with pulverized fuel firing and dry ash removal, the newer development of wet bottom furnaces also began with designs using similar furnace geometry, such as the slagging hopper furnace and the slagging table furnace represented by design (*b*) and (*e*) in Fig. 2. The furnace with slagging hopper has tangential burners directed downward into the hopper (20). The tubing in the hopper as well as that of the walls up to the top of the burners is completely covered with refractory in order to achieve high temperatures and slag flow. The slag-table design uses a similar position of the tangential burners and a similar covering of the furnace walls. The table is to act as ignition surface and to increase combustion time of the pulverized fuel in the furnace.

To reduce radiation from the slagging zone and increase combustion temperatures, later versions of these designs are often fitted with a pronounced waistline of the furnace just above the burners, similar to design (*e*). Arrangement of slagging screens similar to design (*g*) also succeeds in screening off the slagging furnace and raising combustion temperatures. In addition to their screening effect, the screens cool the gases leaving the furnace to a point below their fluid ash temperature level, catch entrained slag drops and drip them to the slagging floor. The slagging screens are formed by evaporator tubes which are studded and covered with high temperature refractory. Generally the more re-

[1] Numbers in parentheses refer to similar numbers in the Bibliography at the end of the article.



F/V—Form factor: Surface to volume ratio, m^2/m^3
q—Combustion rate: Heat released per volume unit, 10^6 kcal/m^3h
a—Open furnace with slagging table
b—Open furnace with waistline
c—Closed furnace with slagging hearth
d—Closed furnace with opposing horizontal burners
e—Vertical cyclone furnace
1) Original design
2) Redesigned furnace
f—Horizontal cyclone furnace, including secondary furnace

Fig. 3—Combustion rates and form factors of slagging furnaces are compared for six different type designs

cent designs employ an effective screening of the slagging furnace in advance of the radiant furnace.

Designs (*a*), (*d*) and (*f*) in Fig. 2 use different approaches. In design (*a*) pulverized fuel and secondary air are injected from above through a burner roof. The flame sweeps uniformly downward across the whole furnace width. After a change of direction, the combustion products pass through the slag screen, *S*, into the radiant furnace.

Design (*d*) is similar but uses horizontal burners in both sidewalls firing against each other. The flame is mixed in the upper part of the slagging furnace and then diverted downward in a right angle. The flow direction is changed again just above the bottom before the gases can leave through the slag screen *S* (13).

In design (*f*) the flame is directed toward the left and down to the bottom of the slagging furnace. This involves two turns and a rebound action of the flame as well as an intensive heating of the furnace bottom, although some of the gas paths are short (24).

The firing in designs (*d*) and (*f*) employs a stronger flame turbulence than in designs (*a*), (*b*) and (*c*).

Arrangement of a vertical cyclone is shown in design (*h*). The slagging furnace is circular in sectional area and has several vertical rows of burners which tangentially inject pulverized fuel and secondary air. A collar of water-cooled, studded and refractory-covered tubes projects deep into the furnace from above. The side view through the furnace clearly shows the similarity with centrifugal collectors and separators. The flow pattern in this furnace therefore follows that of a dust collector with a forced vortex velocity profile. The flame rotates between outside furnace wall and collar, moves downward and over the bottom, then leaves upward through the collar rotating in the same direction within a now smaller radius. Strong turbulence and screening combined with a long combustion path of the pulverized fuel are special characteristics of this design (1, 11).

Design (*i*) in Fig. 2 shows a German version of the horizontal cyclone furnace (26). Pulverized coal and secondary air are injected tangentially into the cyclone through several burners arranged along the depth of the cyclone wall. The design thereby shows a basic difference with respect to cyclone firing used in the United States where the crushed fuel is injected by one large burner at the tip of the cyclone front. The cyclone in design (*i*) also has a collar at the end with strong contraction and a burner arrangement similar to design (*h*). However, combustion takes place here at much higher air and gas velocities. The slag recovered in the cyclone leaves through an opening in the lower part of the cyclone collar into the secondary furnace.

This secondary furnace serves as a second slagging furnace following the cyclone. The gas leaving the cyclone collar with high velocity and the entrained slag strike an almost vertical wall made up of studded and covered water-cooled tubes. Only after another turn do the combustion products pass through the slag screen into the radiant furnace. The fluid slag from the cyclone combines with slag from the secondary furnace on the inclined bottom and leaves through an opening into the watertank of the slag collector.

This type of firing allows a somewhat coarser preparation of the coal than other designs but requires considerably higher pressures for primary and secondary air. It has a very high turbulence and employs extensive screening of the slagging furnaces. Several cyclones of this type can be arranged with one common secondary furnace.

Certain comparisons regarding the characteristic dimensions of the various designs suggest themselves. For some of the slagging furnaces currently in operation, the combustion rates in heat released per volume unit have been plotted in Fig. 3 against the form factor. The latter is made up of the ratio of overall wall surface to volume of the furnace. Although the individual slagging furnaces compared in the graph differ widely in their form and flame travel, a certain relationship appears to be generally valid. For increasing combustion rates the form factor moves up linearly with only slight deviations.

This relationship appears to be confirmed in Fig. 3 by the points (*1*) and (*2*). One of the slagging furnaces was designed for a combustion rate at a form factor considerably beyond the standard relationship. The slagging operation proved to be unsatisfactory since combustion took place partly outside the slagging furnace. The furnace was then redesigned for a lower combustion rate while the form factor remained almost unchanged. The

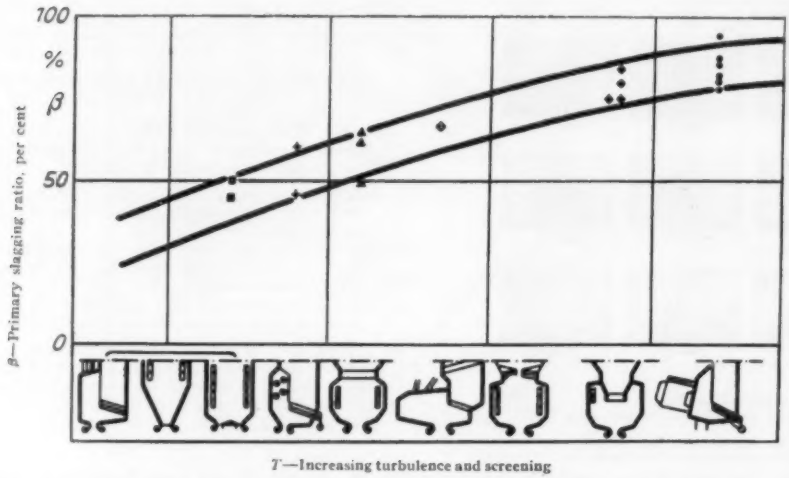


Fig. 4—Slag retention in slagging furnaces is plotted against greater turbulence and increased screening

new characteristics match approximately the relationship shown by the other furnaces. Combustion is now completed within the slagging furnace and slag flow as well as primary slagging ratio meet expectations.

The trend has been toward high combustion rates in slagging furnaces even though it requires a more unfavorable form factor. In these furnaces it is easier to achieve high turbulence of combustion and to arrange a wall screen preceding the radiant furnace. The high flame turbulence makes it possible to complete combustion of the pulverized fuel and the combustible gases within the slagging furnace despite low excess air operation. This also allows better control over the gas temperature drop in the radiant furnace and stabilizes ignition of low volatile coals and at partial load operation. The continuous intensive contact of the flame with all slagging furnace walls improves the retention of the ash particles in the slag flow and thereby increases the primary slagging ratio.

An attempt to classify the slagging furnaces currently in use according to their primary slagging ratio is shown in Fig. 4. The primary slagging ratio is defined as the ratio of ash recovered as furnace slag to ash introduced by the fuel as initially fired, excluding reinjection. Since only a few test results (22, 25) are available for the plot, it merely has comparative value and does not reflect an exact judgment of the various designs especially since the significance of a higher or lower slagging ratio is not rated uniformly by the operators. The graph does show how increasing turbulence in the slagging furnace and stronger screening ahead of the following heat absorbing surfaces improve the primary retention of slag up to about 90 per cent of the ash injected with the coal.

In slagging furnaces all coal ash is transformed into a melted, granulated type slag regardless of the primary slagging ratio. The only exception is the volatilized ash and the ash leaving the stack. The latter depends on the design and efficiency of the dust collectors. Since a moderate primary slagging ratio will result in heavy dust loading through the furnace and heating surfaces, high efficiency dust collectors are required and the quantities of fly ash returned from the collector to the furnace are comparatively large (25).

In slagging furnaces with high primary slagging ratio the dust loading of the gases passing the steam generator is low, thus reducing the ash quantities returned from the collector to the furnace. For the equivalent dust loading of flue gases leaving the stack, the units with a higher slagging ratio generally require less extensive dust collecting equipment. It has, however, been found that slagging furnaces with primary slagging ratios of 85 to 90 per cent experience ash deposits in the convection surfaces which require special cleaning devices such as pellet impingement, vibrators and similar equipment (26).

The fineness of the ash particles leaving the furnace increases with higher slagging ratios and very fine fly ash is more likely to cause deposits on heating surfaces than coarser ash. The ash ingredients which have volatilized during combustion partially condense on the colder heating surfaces and then support the depositing of very fine solid ash particles. Coarser fly ash, of which more appears with moderate primary slagging ratios, has a scrubbing effect and tends to keep the heating surfaces clean. This behavior of fly ash in the convection surfaces is, of course, subject to other influences depending on the constituents of the coal ash. The type of opera-

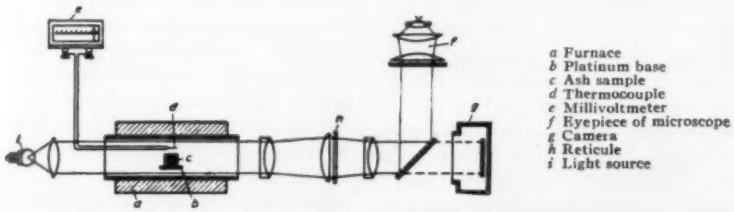
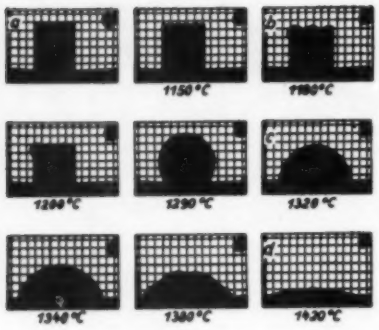


Fig. 5—Schematic arrangement of standardized test equipment with inspection microscope and camera



a Ambient temperature
b Initial deformation temperature, 2155 deg F
c Fusion temperature, 2410 deg F
d Fluid temperature, 2585 deg F

TABLE I—TEMPERATURE DEFINITIONS (ASTM) COMPARED WITH RESULTS IN FIG. 6

The ASTM standards D492–40T (revised 1940) "Sampling coals classed according to ash content" defines three critical points in determining the fusibility of ash.

Initial deformation temperature: The temperature at which the first rounding or bending of the apex of the cone of the test piece takes place.

Softening temperature: The temperature at which the cone of the test piece has fused down to a spherical lump. This is also called fusion temperature.

Fluid Temperature: The temperature at which the cone of the test piece has spread out over the base in a flat layer.

Comparisons between the standard fusion tests as described in above ASTM standards (in Germany known as "Bunte-Baum" tests) and the tests with the heating microscope have shown that the equivalent temperatures of the latter run approximately 180 to 230 deg F higher than do the former.

Fig. 6—Example of ash melting behavior of a Ruhr coal as observed in the Leitz Heating Microscope in Fig. 5

tion, whether at continuous load or with repeated load changes, also influences furnace cleanliness. Slagging furnaces may show operating periods of 5000 hr or more between periods of gas side cleaning.

Suitability of Bituminous Coals for Slagging

Frequently it becomes necessary to determine the suitability of individual bituminous coals or mixtures not previously used in slagging furnaces. Although a test operation for several days at varying loads is still considered the most reliable check, there are a number of methods to examine small samples in the laboratory with results which provide information for full scale use. In addition to ash analysis the melting behavior of the coal ash is usually investigated with the Leitz Heating Microscope (4). Fig. 5 shows the schematic arrangement of this instrument.

The ash sample subject to increasing temperatures, is observed during the test and the main phases are photographed.

An example of such a test is shown in Fig. 6 for an ash from a Ruhr coal. Since preparation and execution of such tests have been standardized in detail, only slight variations in test results may be expected. (See Table I for explanations.)

The fluid temperature of an ash determined in this manner is in the first place an indication of the suitability of coal having that particular ash for slagging operation. The softening and initial deformation temperatures determined during the same test also allow valuable conclusions. Viscosity measurements of fluid slag samples are further indications for coal ash behavior (10, 19).

All methods currently in use for slag examination, however, do not represent the actual conditions existing in the combustion zone during the formation of the fluid slag. The test periods are far too long, for laboratory processes which take hours actually occur in the furnace within fractions of a second. Furthermore, the ash performance is investigated in the laboratory in the absence of the coal, thus eliminating the actual combustion process. More recent research work indicates that a better correlation of testing methods with the melting process in the furnace can be found and thereby provide a more characteristic analysis of the coal ash (32).

The fluid temperatures of ashes from bituminous coals determined in the heating microscope vary with their composition. In Fig. 7 the fluid temperatures of a number of bituminous coals from various sources were determined in reducing atmosphere and plotted against the sum of the SiO_2 and Al_2O_3 content in their ash.

Since the samples were selected for their high fusion temperature the plot does not represent average conditions for German bituminous coals. It is known that silicates and aluminates generally constitute the larger part of bituminous coal ashes on which lime and iron oxides therefore act as fluxes (6, 21). Brown coal ashes with high lime content, incidentally, behave in the opposite manner (5, 17). The plot in Fig. 7 shows that coal ashes with high SiO_2 plus Al_2O_3 content also have high fluid temperatures, some of them exceeding 3000 F.

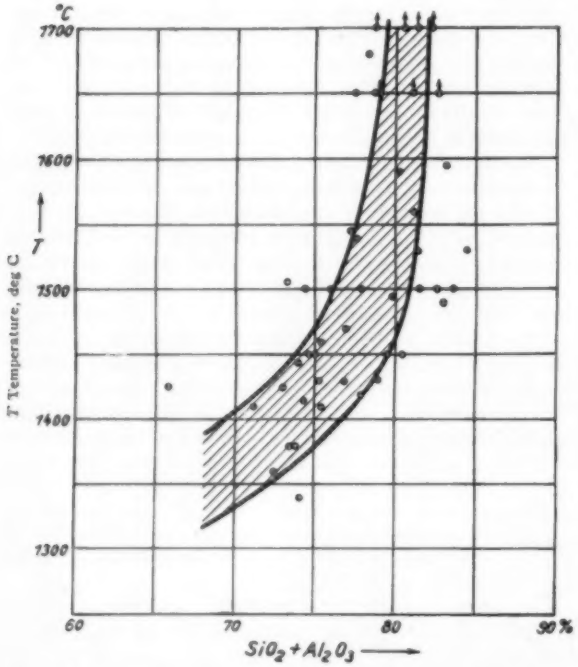


Fig. 7—Fluid temperatures of bituminous coal ashes in reducing atmosphere versus SiO_2 plus Al_2O_3 ash constituents

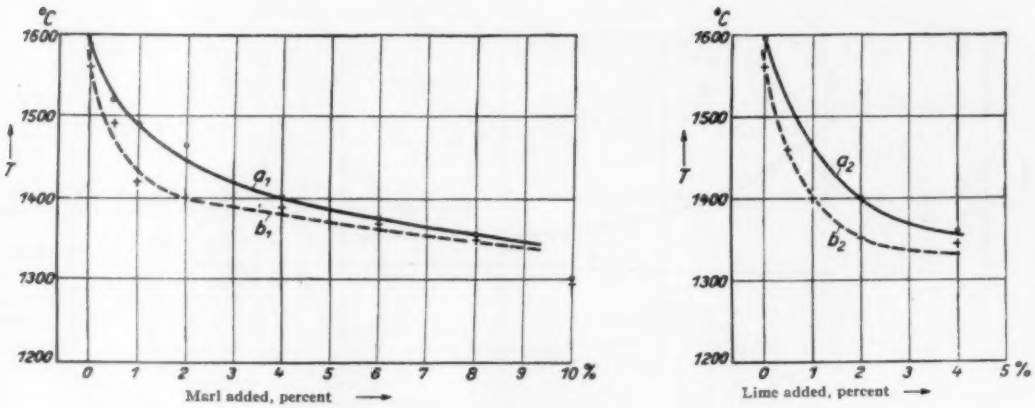


Fig. 8—Reduction of fusion and fluid temperature of a bituminous coal ash by lime or marl addition to fuel

Most German bituminous coals have fluid temperatures up to about 1650 F and are therefore generally well suited for slagging furnaces. Coals with higher fluid ash temperatures have so far not been fired in slagging furnaces or only in mixtures with better coal grades.

When a new power plant was recently planned it became necessary to consider the use of a bituminous coal with fluid ash temperatures of 2870 F to 3090 F. At the same time it appeared desirable to make use of the advantages offered by slagging furnaces if at all possible. Large scale tests with the coal in various existing types of slagging furnaces were unsatisfactory. Even high secondary air temperatures, low excess air ratios and high combustion rates could not support combustion temperatures in the slagging furnace sufficiently above the fluid ash temperature. In the present state of the art of fuel firing, it would be difficult to justify on an economic basis any further increase in combustion temperature. The contemplated coal grade and others with similar high fluid ash temperatures might therefore have been considered unsuitable for slagging furnaces. However, by comparing the analysis of bituminous coal ashes with higher and lower fluid temperatures according to Fig. 7 the author concluded that the fluid ash temperature of the contemplated difficult coal could in all probability be considereably lowered by only slight addition of CaO. Laboratory tests with the heating microscope confirmed this conclusion. Various amounts of marl or lime (with an analysis as listed in Table II together with that of the test coal and ash) were added to the coal sample ahead of the ashing process.

TABLE II—ANALYSIS OF TEST COAL AND ASH, SUGGESTED ADDITIVES*

Test Coal	
Moisture, %	8.3
Ash, %	17.0
Volatiles, (moisture and ash free), %	16.1
Lower heating value, Btu/lb.	12,380

Test Coal Ash	
SiO_2, %	49.1
Al_2O_3, %	32.8
Fe_2O_3, %	6.8
CaO, %	2.10
MgO, %	1.95
Balance, %	7.25
Fluid temp. (oxyd. atm.), F	2895
Fluid temp. (red. atm.), F	>3090

Marl Additive	
$CaCO_3$, %	90.15
$MgCO_3$, %	2.40
$CaSO_4$, %	0.20
$CaSiO_3$, %	0.10
$MgSiO_3$, %	0.15
Free SiO_2, %	5.15
Fe_2O_3, %	0.65
Al_2O_3, %	0.75
Balance, %	0.45

Limestone Additive	
$Ca(OH)_2$, %	93.6
CaO, %	1.2
$CaCO_3$, %	4.4
Al_2O_3, %	0.7
MgO, %	0.1
Balance, %	...

* Suggested additives said to reduce the fluid temperature of the ash of a given coal and hence render it more adaptable to slagging furnace service.

Effect of Additives

The change of fluid and softening temperatures of the test coal ash with various amounts of additives to the coal is plotted in Fig. 8. A 1 per cent addition of marl to the coal already reduces the fluid temperature by about 180 deg F (Curve a_2). Increasing the addition of marl and lime to 2 per cent decreased the fluid ash temperature by 260 deg F and 350 deg F, respectively. The initial deformation temperatures showed a very similar behavior (curves b_1 and b_2). It was therefore to be expected that small additions of marl and lime to coals otherwise not suited for slagging furnaces would sufficiently change the ash melting behavior to bring it approximately into line with other suitable and proved bituminous coals.

The large scale tests decided upon after the favorable results in the laboratory were performed with two slagging furnaces in units of 140,000 and 176,000 lb per hr steam capacity. They confirm the preceding considerations as well as the laboratory tests with the heating microscope. Both slagging furnaces could be operated with the difficult test coal having about 1 per cent marl added to the initial coal weight at all loads down to between 37 per cent and 40 per cent with fully satisfactory slag flow. Larger additions of lime or marl will allow slagging operation with this difficult coal at even lower loads. The cost of the marl addition to the coal in this case amounted to about 0.3 per cent of the fuel cost and should be at a comparable value at other places as well since lime is easily available almost anywhere.

The results made it possible to decide in favor of slagging operation, especially since the fuel program of the new plant included other bituminous coals with easier melting ashes and a mixing of these with the difficult coal would allow, at least temporarily, a substitute for lime addition.

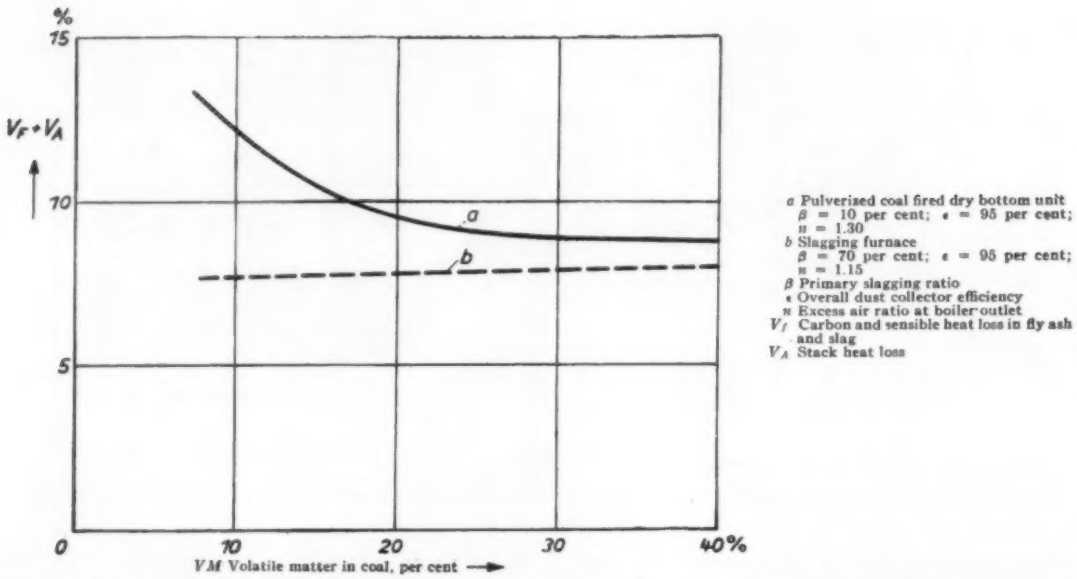


Fig. 9—Carbon and stack heat losses; wet bottom, dry bottom units, coal, 15 per cent ash at 320 F exit temp

A comparable case, though with different background, occurred with a slagging unit of 140,000 lb/hr capacity for Rhenish raw brown coal. The coal fired in this unit, which had been in operation for some time, had a high lime content in its ash (approximately 45 per cent CaO) and caused difficulties in operation. A 10 per cent addition of bituminous coal with a high ash content of about 20 per cent in which the SiO_2 measures about 48 per cent improved the slag flow to such an extent that satisfactory slagging operation could be extended from full load down to 47 per cent load (5, 27).

Influence on Boiler Efficiency

Bituminous Coal Firing. In comparison with dry bottom firing, slagging furnace operation provides a better efficiency gain with bituminous coals having low and medium volatile content than it does with high volatiles. The carbon losses in the fly ash which increase with lower volatiles are practically eliminated in slagging furnaces because all ash is converted to slag in which all carbon content is burnt out. Slagging operation, however, does involve a considerable loss due to the sensible heat in the slag removed. The sensible heat loss in the flue gas, on the other hand, is lower than that of standard pulverized fuel firing systems because slagging furnaces operate with very low excess air ratios of 1.07 to 1.15 over the entire range of slagging operation.

An example for a bituminous coal with an ash content of 15 per cent is shown in Fig. 9 where the sum of carbon and stack heat losses are plotted against volatile content of the fuel for both firing systems. For coals with 10 per cent volatiles the slagging operation gains about 4.5 efficiency points and with 40 per cent volatiles about 1.0 efficiency point.

Ash content above 15 per cent will increase the losses of slagging units (curve *b*) while a lower ash content will decrease them. Dry bottom units (curve *a*) are only slightly affected by varying ash content. For bituminous coals up to comparatively high ash content the slagging units achieve higher boiler efficiencies and a flatter efficiency characteristic than do other firing systems.

Raw Brown Coal Firing. Slagging furnaces for raw brown coal so far have been built only occasionally because the problems of ash removal as well as the possibilities of achieving a higher unit efficiency are usually different from those for bituminous coal. A large part of the German raw brown coal mining output is processed into briquettes for industrial and domestic use. The briquetting process requires a raw coal with low ash content which leaves the larger share of higher ash coals for

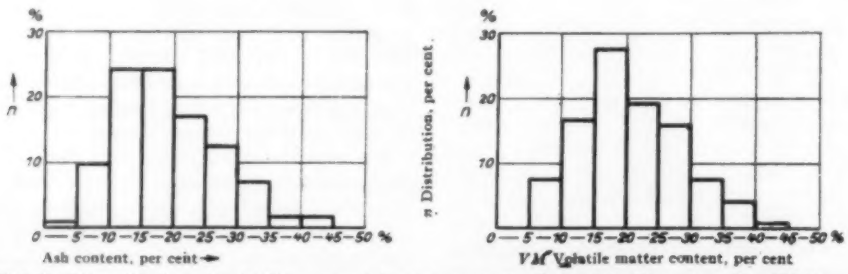
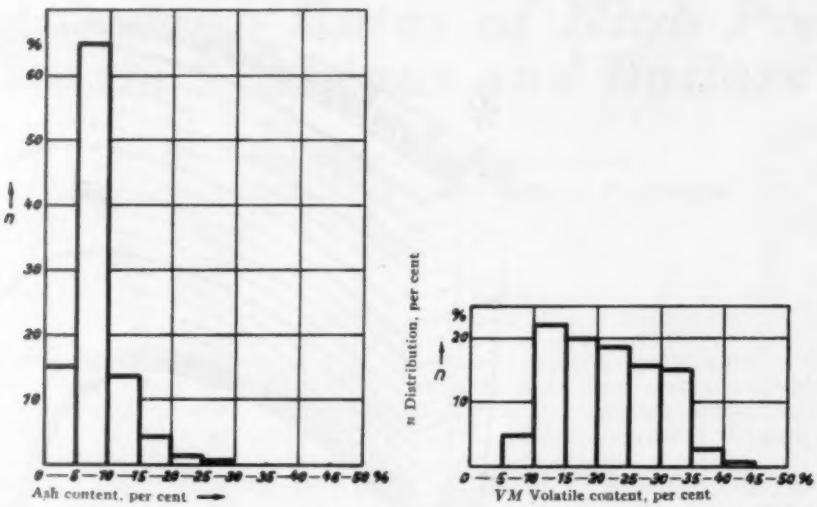

%
30
20
10
n
0 — 5 — 10 — 15 — 20 — 25 — 30 — 35 — 40 — 45 — 50 %
Ash content, per cent
n Distribution, per cent
%
30
20
10
n
0 — 5 — 10 — 15 — 20 — 25 — 30 — 35 — 40 — 45 — 50 %
VM Volatile matter content, per cent

Fig. 10—Distribution of ash and volatile content (moisture and ash free) in 54 units. See Bibliography (23).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Ash content, per cent
n Distribution, per cent
%
20
10
n
0 — 5 — 10 — 15 — 20 — 25 — 30 — 35 — 40 — 45 — 50 %
VM Volatile content, per cent

Fig. 11—Distribution of ash and volatile content (moisture and ash free) among 140 coals See Bibliography (8)

firing in power plants. Due to the low heating value of the raw brown coal of 2150 to 4000 Btu per lb (LHV) with a moisture content of 48 to 60 per cent, the loss of sensible heat in the fluid slag has a larger negative influence on the overall unit efficiency than it does for bituminous coals with their considerably higher heat content. The slagging furnace for raw brown coal with low and medium ash content, however, offers a higher unit efficiency than do other firing systems.

Conclusion

The slagging furnace in Germany has undergone an interesting development with a variety of designs and is at present the preferred firing system for bituminous coals in units of larger capacity. The fuel program for this type of firing encompasses a wide range of coals and, with the help of additives, can even include coals with high fluid ash temperatures. In this connection Fig. 10 and Fig. 11 are of interest. Fig. 10 shows the bituminous coals fired in 54 different steam generators with slagging furnaces, ordered as to their content in ash and volatile matter. Fig. 11 shows the frequency of ash and volatiles in 140 different coals from a variety of sources fired in a single slagging furnace over a longer period of time.

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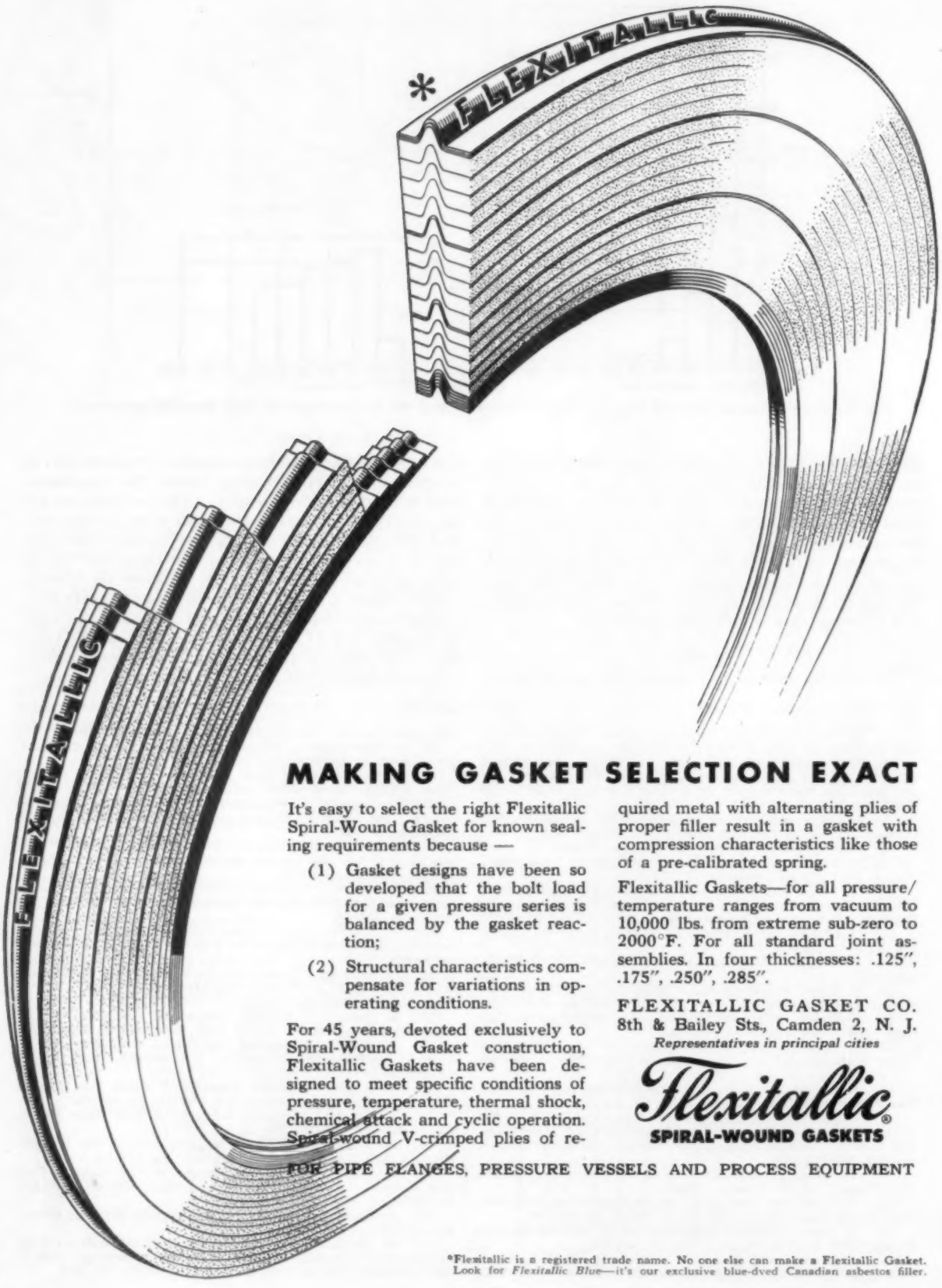

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Forced Outage Rates of High Pressure Steam Turbines and Boilers*

AIEE Subcommittee on Application of Probability Methods to Power System Problems

Introduction

This report is a presentation of the final results of a five year nation-wide outage survey of horizontal steam turbine-generators operating at pressures of 700 psi or greater and rated at or over 20,000 kw condensing or 10,000 kw superposed, and of boilers with continuous rated capacity of 200,000 pounds per hour or more and with outlet pressures of 700 psi or greater.

The primary objective of the study was to obtain the forced outage rates of the above classes of equipment for use in the application of probability methods to power system problems involving such facilities.

The data collected by the Prime Movers Committee of the Edison Electric Institute for the years 1950 to 1954 inclusive were analyzed by Mr. Veazey M. Cook, System Engineering Department, Consolidated Edison Company of New York, Inc.

Outage Definitions

Outages as classified in this report include all those, regardless of length, which existed during the heavy load portions of the day. Each day on which such outage existed is counted as a full day of outage. Outages confined to light load hours of the day are disregarded. The heavy load period of the day may vary somewhat from system to system, but approximately it is the period from 7:00 a.m. to 10:00 p.m.

Instructions on classification of outages as issued to the operating companies are included herein as Appendix A for turbines and Appendix B for boilers.

* Paper presented before the AIEE Winter General Meeting, New York, N. Y., Jan. 21–25, 1957.

Tables of Outage Experience

Tables I and II for turbines and III and IV for boilers show the performance or status of turbines and boilers during the five year period 1950–1954, both for all days and for weekdays excluding Saturdays, Sundays and major holidays.

The availability factor for turbines may be found from Table I as the sum of the percentage for unit-days available but not operated and the percentage of unit-days operated, both of which are expressed as a percentage of total unit-days installed. The same factor for boilers may be obtained from Table III. These factors for the three pressure groups are as follows:

	Pressures Less Than 1000 psi	Pressures From 1000 to 1350 psi	Pressures More Than 1350 psi
Turbines	93.20	91.95	89.64
Boilers	91.79	89.66	88.84

Forced Outage Rate for Turbines

The forced outage rates for turbines are shown in Table V and are summarized for each annual survey as follows:

	Forced Outage Rate, %					
	1950	1951	1952	1953	1954	1950–54
Pressures less than 1000 psi	1.42	0.66	0.43	0.73	0.67	0.78
Pressures from 1000 to 1350 psi	1.59	0.81	0.82	0.43	1.86	1.10
Pressures more than 1350 psi	0.15	0.75	0.71	1.07	0.99	0.89

The above outage rates are based on outages chargeable only to the turbine-generator, condenser and own directly associated auxiliaries, and exclude other causes of outage such as boiler, transmission line, bus or transformer unavailability.

TABLE I—SUMMARY OF PERFORMANCE OF TURBINE GENERATORS, 1950–1954, ALL DAYS

Units Operating at Pressures of 700 psi or Greater and Rated at or Over 20,000 Kw Condensing or 10,000 Kw Superposed

	Pressures Less Than 1000 psi			Pressures From 1000 to 1350 psi			Pressures More Than 1350 psi		
	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of turbine-generators reported on	880*	..	..	523*	..	..	222*	..	..
On forced outage, due to unit	2529	0.80	0.87	2043	1.08	1.20	654	0.84	0.94
On forced outage, due to other cause	1347	0.42	0.47	1145	0.61	0.67	753	0.96	1.08
Total forced outage	3876	1.22	1.34	3188	1.69	1.87	1407	1.80	2.02
Week day outage transferable to week end and week end outage	2169	0.68	0.75	1593	0.84	0.93	1249	1.59	1.79
On scheduled outage, due to unit	12,993	4.09	4.48	8828	4.67	5.18	4304	5.49	6.18
On scheduled outage, due to other cause	2562	0.81	0.88	1607	0.85	0.94	1162	1.48	1.67
Total scheduled outage	15,555	4.90	5.36	10,435	5.52	6.12	5466	6.97	7.85
Available but not operated	6315	1.99	2.18	3318	1.76	1.95	605	0.77	0.87
In operation	289,793	91.21	100.00	170,481	90.19	100.00	69,645	88.87	100.00
Total unit-days installed	317,708	100.00	..	189,015	100.00	..	78,372	100.00	..
Not installed	3685	..	..	1995	..	..	2696	..	..
Total all unit-days	321,393	..	..	191,010	..	..	81,068	..	..

NOTE: Partial turbine-generator outages are neglected.
Table covers status during heavy load period of day only.

* Unit-Years.

TABLE II—SUMMARY OF PERFORMANCE OF TURBINE GENERATORS, 1950–1954, WEEK DAYS ONLY

Units Operating at Pressures of 700 psi or Greater and Rated at or Over 20,000 Kw Condensing or 10,000 Kw Superposed

	Pressures Less Than 1000 psi			Pressures From 1000 to 1350 psi			Pressures More Than 1350 psi		
	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of turbine-generators reported on	880*	..	..	523*	..	..	222*	..	..
On forced outage, due to unit	1611	0.73	0.78	1324	1.01	1.09	432	0.79	0.87
On forced outage, due to other cause	728	0.33	0.36	649	0.50	0.54	449	0.83	0.90
Total forced outage	2339	1.06	1.14	1973	1.51	1.63	881	1.62	1.77
Week day outage transferable to week end	436	0.20	0.21	241	0.18	0.20	145	0.26	0.29
On scheduled outage, due to unit	8796	4.00	4.28	5943	4.54	4.90	2856	5.26	5.73
On scheduled outage, due to other cause	1347	.61	.66	873	.67	.72	574	1.06	1.15
Total scheduled outage	10,143	4.61	4.94	6816	5.21	5.62	3430	6.32	6.88
Available but not operated	1599	0.73	0.78	681	0.52	0.56	52	0.10	0.10
In operation	205,459	93.40	100.00	121,188	92.58	100.00	49,824	91.70	100.00
Total unit-days installed	219,975	100.00	..	130,899	100.00	..	54,332	100.00	..
Not installed	2537	..	..	1374	..	..	1856	..	..
Total all unit-days	222,512	..	..	132,273	..	..	56,188	..	..

NOTE: Partial turbine-generator outages are neglected.
Table covers status during heavy load period of day only.

* Unit-Years.

FORCED OUTAGE RATE FOR BOILERS

The forced outage rates for boilers are shown in Table VI and are summarized for each annual survey as follows:

	Forced Outage Rate, %					
	1950	1951	1952	1953	1954	1950–54
Pressures less than 1000 psi	0.89	0.55	0.78	0.89	1.20	0.84
Pressures from 1000 to 1350 pr.	1.70	1.30	1.36	1.14	1.21	1.33
Pressures more than 1350 psi	0.95	0.70	0.70	0.82	1.19	0.90

The above outage rates are based on outages chargeable only to the boiler and its own directly associated auxiliaries such as fans, boiler feed pumps and essential fuel handling equipment. The effect of outages from other causes such as main turbine-generator, transmission line, station feed-water or fuel are excluded.

UNIT-TYPE INSTALLATION

For unit-type installations where the boiler being out of service imposes removal of the turbine-generator unit from service, and vice versa, the service probability of the complete boiler plus turbine-generator unit is computed as the product of the decimal availability of turbine times that of the boiler. For example;

Forced outage rate of individual units above 1350 psi
Turbine 0.89% or 0.0089 decimal
Boiler 0.90% or 0.0090 decimal

Service probability, based on forced outages
Turbine 1.0000 − 0.0089 = 0.9911
Boiler 1.0000 − 0.0090 = 0.9910
Total unit = 0.9911 × 0.9910 = 0.98218
= 98.218%

Forced outage rate of total unit is
100% − 98.218% = 1.782%

REFERENCES

1. "Outage Rates of Steam Turbines and Boilers and of Hydro Units," AIEE Committee Report. *AIEE Transactions*, vol. 68, pt. I, 1949, pp. 450–457.

2. "Forced Outage Rates of High-Pressure Steam Turbines and Boilers," AIEE Committee Report. *AIEE Transactions*, vol. 73, pt. III, 1954, pp. 1438–1442.

ACKNOWLEDGEMENTS

The Committee acknowledges with appreciation the constructive suggestions of Messrs. R. N. Slinger, General Electric Co. and Sherwin H. Wright, Bechtel Corp.

TABLE V—DURATION AND FREQUENCY OF OCCURRENCE OF TURBINE-GENERATOR FORCED OUTAGES DURING 1950–1954

Units Operating At Pressures Of 700 psi Or Greater And Rated At Or Over 20,000 Kw Condensing Or 10,000 Kw Superposed*

Outage Duration In Days	Pressures Less Than 1000 psi		Pressures From 1000 to 1350 psi		Pressures More Than 1350 psi	
	Actual	Adjusted*	Actual	Adjusted*	Actual	Adjusted*
1	277	181	193	149	66	50
2	91	51	78	54	25	22
3	40	17	40	20	11	5
4	20	20	11	11	8	8
5	13	13	5	5	5	5
6	2	2	5	5	4	4
7	4	4	6	6	1	1
8	2	2	5	5	3	3
9	3	3	5	5	1	1
10	5	5	2	2	0	0
11–15	8	8	8	8	1	1
16–25	11	11	8	8	2	2
26–50	10	10	9	9	3	3
51–100	8	8	6	6	2	2
101 Up	3	3	2	2	1	1
Total number of occurrences (A)	497	338	383	295	133	118
Unit days of outage included above (B)	2531	2286	2074	1922	654	624
Unit days of outage prior to period	2	2	31	31	0	0
Unit days of outage overrunning period	0	0	0	0	0	0
Unit days of outage in period (C)	2529	2284	2043	1891	654	624
Average duration of one outage: days B/A	5.09	6.76	5.42	6.52	4.92	5.29
Unit days of full operation in period	289,793	289,793	170,481	170,481	69,645	69,645
Unit days exposed in period (D)	292,322	292,077	172,524	172,372	70,299	70,269
Days exposed per outage D/A	588	864	450	584	529	596
Forced outage rate, % C/D	0.87	0.78	1.18	1.10	0.93	0.89
Number of turbine-generators reported on**	880	..	523	..	222	..

NOTE: This table includes only outages chargeable to unit alone.

* Adjusted for excess of short outages on weekends.
** Unit Years.

TABLE III—SUMMARY OF PERFORMANCE OF BOILERS, 1950–1954, ALL DAYS

Boilers With Continuous Rated Capacity Of 200,000 Lbs Per Hour Or More And With Outlet Pressure Of 700 psi Or Greater

		Pressures Less Than 1000 psi			Pressures From 1000 to 1350 psi			Pressures More Than 1350 psi		
		Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of boilers reported on		1066*	..	..	657*	..	..	434*	..	..
On forced outage, due to unit	Full	2624	0.68	0.75	2457	1.03	1.18	1282	0.82	0.94
	Partial	1256	0.33	0.36	1330	0.56	0.64	413	0.27	0.31
On forced outage, due to other cause	Full	1174	0.31	0.34	859	0.36	0.41	800	0.52	0.59
	Partial	35	0.01	0.01	28	0.01	0.01	50	0.03	0.04
On maintenance outage, due to unit	Full	5848	1.52	1.68	5318	2.23	2.55	4011	2.58	2.96
	Partial	624	0.16	0.18	691	0.29	0.33	248	0.16	0.18
On maintenance outage, due to other cause	Full	1597	0.41	0.46	1173	0.49	0.56	811	0.52	0.60
	Partial	16	..	..	30	0.01	0.02	14	0.01	0.01
On overhaul outage, due to unit	Full	15,738	4.08	4.52	11,391	4.78	5.47	8744	5.62	6.45
	Partial	33	0.01	0.01	28	0.01	0.01	4	..	..
On overhaul outage, due to other cause	Full	2661	0.69	0.76	1355	0.57	0.65	978	0.63	0.72
	Partial	55	0.01	0.01	8	..	..	1	..	..
Available but not operated (excludes partial)		5567	1.44	1.60	5551	2.33	2.67	2547	1.64	1.88
In operation (excludes partial operation)		348,432	90.35	100.00	208,365	87.33	100.00	135,633	87.20	100.00
Total unit-days installed		385,660	100.00	..	238,585	100.00	..	155,541	100.00	..
Not installed		3668	..	..	1363	..	..	2961	..	..
Total all unit-days		389,328	..	..	239,948	..	..	158,502	..	..

NOTE: Table covers status during heavy load period of day only.

* Unit-Years.

TABLE IV—SUMMARY OF PERFORMANCE OF BOILERS, 1950–1954, WEEK DAYS ONLY

Boilers With Continuous Rated Capacity Of 200,000 Lbs Per Hour Or More And With Outlet Pressure Of 700 psi Or Greater

		Pressures Less Than 1000 psi			Pressures From 1000 to 1350 psi			Pressures More Than 1350 psi		
		Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating	Number of Unit-Days	Per Cent Based on Unit-Days Installed	Per Cent Based on Unit-Days Operating
Number of boilers reported on		1066*	..	..	657*	..	..	434*	..	..
On forced outage, due to unit	Full	1655	0.62	0.67	1506	0.91	1.01	769	0.71	0.79
	Partial	812	0.31	0.33	880	0.53	0.59	200	0.18	0.21
On forced outage, due to other cause	Full	745	0.28	0.30	530	0.32	0.36	505	0.47	0.52
	Partial	22	0.01	0.01	21	0.01	0.01	23	0.02	0.02
On maintenance outage, due to unit	Full	2526	0.95	1.03	2178	1.32	1.46	1519	1.41	1.57
	Partial	419	0.16	0.17	486	0.30	0.33	169	0.16	0.18
On maintenance outage, due to other cause	Full	565	0.21	0.23	520	0.32	0.35	334	0.31	0.35
	Partial	5	..	..	23	0.02	0.02	6	0.01	0.01
On overhaul outage, due to unit	Full	10,743	4.02	4.36	7771	4.70	5.21	5938	5.51	6.13
	Partial	22	0.01	0.01	20	0.01	0.01	4	..	..
On overhaul outage, due to other cause	Full	1698	0.64	0.69	891	0.54	0.60	637	0.59	0.66
	Partial	37	0.02	0.02	6	..	..	1	..	..
Available but not operated (excludes partial)		1436	0.54	0.58	1324	0.80	0.89	785	0.73	0.81
In operation (excludes partial operation)		246,249	92.23	100.00	149,049	90.22	100.00	96,877	89.90	100.00
Total unit-days installed		267,006	100.00	..	165,207	100.00	..	107,776	100.00	..
Not installed		2524	..	..	936	..	..	2035	..	..
Total all unit-days		269,530	..	..	166,343	..	..	109,811	..	..

NOTE: Table covers status during heavy load period of day only.

* Unit Years.

TABLE VI—DURATION AND FREQUENCY OF OCCURRENCE OF BOILER FORCED OUTAGES DURING 1950–1954

Boilers With Continuous Rated Capacity Of 200,000 Lbs Per Hour Or More And With Outlet Pressure Of 700 psi Or Greater

Outage Duration In Days	Pressures Less Than 1000 psi		Pressures From 1000 to 1350 psi		Pressures More Than 1350 psi	
	Actual	Adjusted*	Actual	Adjusted*	Actual	Adjusted*
1	650	537½	744½	659½	363	279
2	341½	276½	358½	279½	181	121½
3	139½	124	142½	118	79	62
4	69	69	65	65	44	44
5	36½	36½	40½	40½	15½	15½
6	19	19	17½	17½	10½	10½
7	10	10	5½	5½	9	9
8	10½	10½	9	9	2	2
9	3	3	5	5	0	0
10	5½	5½	7	7	0	0
11–15	15	15	12½	12½	9½	9½
16–25	7½	7½	5	5	1½	1½
26–50	2	2	3½	3½	0	0
51–100	2½	2½	1	1	0	0
101 Up	1	1	0	0	0	0
Total number of occurrences (A)	1312½	1119½	1417	1228½	715	554½
Unit days of outage	3252	2963	3122	2805½	1513½	1259½
Unit days of outage prior to period	0	0	0	0	25	25
Unit days of outage overrunning period	0	0	0	0	0	0
Unit days of outage in period (C)	3252	2963	3122	2805½	1488½	1234½
Average duration of one outage: days B/A	2.48	2.65	2.20	2.28	2.12	2.27
Unit days of full operation in period	348,432	348,432	208,365	208,365	135,633	135,633
Unit days exposed in period (D)	351,684	351,395	211,487	211,170½	137,121½	136,867½
Days exposed per outage D/A	268	314	149	172	192	247
Forced outage rate, % C/D	0.92	0.84	1.48	1.33	1.09	0.90
Number of boilers reported on**	1066	..	657	..	434	..

NOTE: This table includes only outages chargeable to unit alone. One-half of actual partial outage days and one-half of the number of partial capacity outages are included.

* Adjusted for excess of short outages on weekends.
** Unit Years.

APPENDIX A—EDISON ELECTRIC INSTITUTE COMMITTEE ON PRIME MOVERS—SUBCOMMITTEE ON TURBINES

Explanatory Notes to Accompany Graphic Questionnaire "System Summary—Daily Record of Steam Turbine Operation and Outage"

Purpose: This questionnaire is distributed to obtain data needed for studies of reserve requirements.

Sample Form: On the accompanying sample chart six months'

experience data for a system of five units have been entered to illustrate the use of the form. Systems reporting on 1 to 3 units can put 12 months on one page; on 4 to 6 units, 6 months on one page, on 7 to 9 units, 4 months on one page; etc.

Unit Identification Etc.: The descriptive data for the individual units is the same as that requested on the regular turbine subcommittee questionnaire.

Reported Outage: Any outage, regardless of length, that occurred or existed during the peak portion of the day is to be counted as one full day of outage, while an outage which was confined to off-peak hours of the day should be disregarded. Cases of successive non overlapping outages on the same day will have to be covered by remarks on the reverse side of the sheet. Outage days should be classified as described below.

Reduced Capacity Operation: Cases of temporary operation at materially reduced capacity will have to be handled as remarks, giving capacity loss and dates.

Transferable Outage: Occasionally, on systems having a temporary super-abundance of reserve capacity, units may have been out during the peak hours of weekdays for work which if the reserve had been normal could and would have been transferred and confined to off-peak hours of the day or to a nearby weekend or holiday period. These outages are classed as transferable.

Scheduled Outage: A scheduled outage is one widely controllable as to time of occurrence so that it might have been or was postponed from one season to another or even to another year. Such outages will usually have been planned months in advance. Annual overhaul is a typical scheduled outage. Scheduled outages are further classified as due to the unit (turbo-generator, condenser and own auxiliaries): or as due to other causes such as: boiler, station or system rearrangement; or reconstruction of a unit to increase capacity, change frequency, etc. as contrasted with reconstruction because of an excessive failure rate.

Forced Outages: A forced outage is one due to causes requiring that the unit be taken out of service at once or as soon thereafter as possible. This includes cases where the cause of the outage is of such nature that the unit is not removed from service until the off-peak period of the same day or following weekend and where the time for repairs extends beyond the off-peak period, in which case the outage is classified as forced during the time extended beyond the off-peak period. Outages on weekends and holidays will be given separate treatment in the analysis of the returns; so that forced outages which were postponed to such days should be reported in the same way as others. Forced outages are further classified as due to the unit (turbo-generator, condenser and own auxiliaries), or as due to other causes such as boiler or transmission line unavailability, flood, bus failure, etc.

Combined Forced and Scheduled Outage: In certain cases of long forced outage the opportunity may have been utilized to schedule necessary overhaul work at the same time. The total duration of the outage may then have been determined by the overhaul. Since the primary interest of this questionnaire is forced outage, it is requested that in such cases the approximate outage time which would have been required without the overhaul be marked as forced outage and the remainder as scheduled outage.

Days Operated: If on any given day a unit was in service, i.e., actually operated with switches closed to station bus for any length of time, however short, one full day of operation should be counted, unless a reported outage as defined above occurred on the same day.

Days Not Installed: Days prior to initial operation or following retirement of a unit should be marked days not installed. Days on which the generator was left uncoupled for operation as a synchronous condenser should also be marked days not installed.

Days Available But Not Operated: Obviously the days remaining after identifying outage days, days operated and days not installed are days available but not operated.

Treatment of Compound Units: In the case of three-element cross-compound units; if the elements are regularly arranged so that the unit can be operated with any one element out, the elements should be reported as separate units.

APPENDIX B—EDISON ELECTRIC INSTITUTE COMMITTEE ON PRIME MOVERS—BOILER SUBCOMMITTEE

Explanatory Notes to Accompany Graphic Questionnaire "System Summary—Daily Record of Steam Boiler Operation and Outage"

Purpose: This questionnaire is distributed to obtain data desired as a basis for determining reserve requirements, and supplements a similar questionnaire on turbine outage. It is recognized that the greater part of boiler outage time is for preventive maintenance work in anticipation of forced outage, which work can either be evenly distributed in time or scheduled for off-peak seasons; that the amount and frequency of such work will generally be determined by the design features of the boilers and the characteristics of the fuel burned; and that consequently the maintenance requirements must be determined by local experience or by particular analogy. It is also apparent that in some cases the necessary reserve for maintenance will permit absorption of a considerable amount of forced or emergency boiler outage, while in other cases the maintenance schedule is so crowded that any other outages must come out of additional reserves. None the less it seems desirable to attempt to determine the prospective incidence of forced boiler outage.

Sample Form: On the accompanying sample chart experience data, for a system having eight boilers of reportable size, are entered to illustrate the use of the form. Systems reporting on 1 to 3 units can report 6 months on one page; on 4 to 6 units, 3 months on one page; on 7 to 9 units, 2 months on one page, etc.

Boiler Unit: The boiler unit will be considered to include all components, fittings, piping, ducts and auxiliaries except those used or designed to be used in common with other boilers.

Reported Outages: Any outage, regardless of length, which existed or occurred during the peak load portion of the day should be counted as one full day of outage, while an outage which was confined to off-peak hours of the day should be disregarded. Cases of successive non-overlapping outages on the same day will have to be covered by remarks on the reverse side of the sheet. Outage days should be classified as described below.

Partial Outage: Where outage of some component, such as a mill or a fan, results in reducing capacity by a major fraction, as one-half or one-third, that outage should be reported as a fractional capacity outage in the manner indicated on the form. Cases in which boilers either after or in anticipation of failure were repaired or altered for temporary operation at materially reduced capacity should also be reported as partial outages.

Overhaul Outage: An overhaul outage is one widely controllable as to time of occurrence so that if desired it might have been or was avoided during the peak load season of the year. Such outages will generally have been scheduled months in advance. Overhaul outages are further classified as due to unit, e.g., for renewal or repair of components or for correction of defects of the boiler itself or of its own auxiliaries; or as due to other causes, such as station rearrangement or alteration to increase capacity or to change the type of combustion equipment, etc.

Maintenance Outage: A maintenance outage is one which cannot be postponed from one season to another but which can be assigned in advance so as to maintain an even or a minimum amount of simultaneous outage, or to utilize weekend time. Maintenance outages are further classified as due to unit or to other cause. A typical maintenance outage due to unit might be renewal of stoker parts or of furnace refractory in anticipation of failure; while one due to other cause might be replacement of a steam header valve beyond the boiler stop valve.

Forced Outage: A forced outage is one due to causes requiring that the unit be taken out of service at once or as soon thereafter as possible. This includes cases where the cause of the outage is of such nature that the unit is not removed from service until the off-peak period of the same day or following weekend and where the time for repairs extends beyond the off-peak period, in which case the outage is classified as forced during the time extended beyond the off-peak period. Forced outages are further classified as due to unit or to other causes. A typical forced outage due to unit might be a tube rupture or the failure of the fan drive. A forced outage due to other cause might result from failure of feedwater or coal supply.

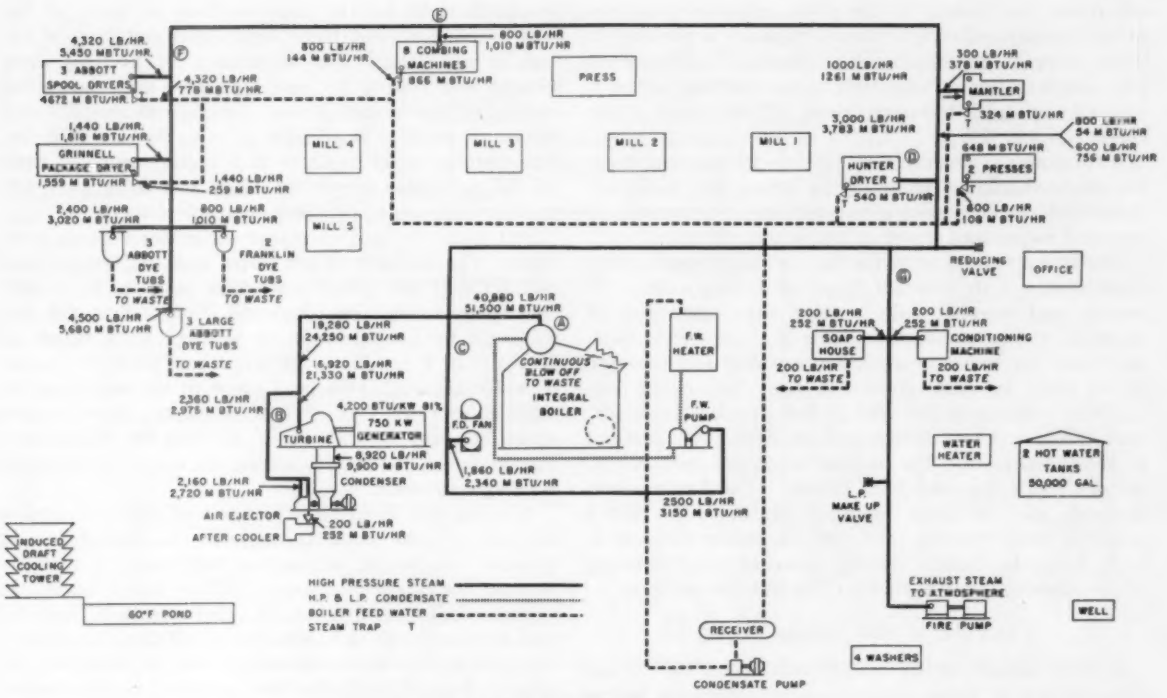
Combined Forced and Overhaul Outage: In certain cases of long forced outage the opportunity may have been utilized to schedule necessary overhaul work at the same time. The total duration of the outage may then have been determined by the overhaul. Since the primary interest of this questionnaire is forced outage, it is requested that in such cases the approximate outage time which would have been required without the overhaul be marked as forced outage and the remainder as overhaul outage.

Days Operated: If on any given day a boiler was burning fuel for any length of time, however short and whether banked or steaming, one full day of operation should be counted unless a reported outage as defined above occurred on the same day.

Days Not Installed: Days prior to initial operation or following retirement of a boiler should be marked days not installed.

Days Available but Not Operated: Obviously the days remaining after identifying outage days, days operated and days not installed are days available but not operated. Days available will include days laid up.

Operating Rate: The average operating rate is equal to the total output in lb of steam divided by the product of hours steaming and the maximum continuous rating in lb of steam per hour. The usual maximum operating rate is equal to the maximum lb of steam per hour at which the boiler is usually operated (in absence of contingencies) divided by the maximum continuous rating in lb of steam per hour.



FLOW DIAGRAM, FULL OPERATING LOAD
STUDY No. B-120

Fig. 1—Heat balance diagram above illustrates the major uses of high pressure steam within a textile plant under study

*Heat Balance Studies In Textile Plants**

The textile industry, in the author's opinion, still tends to view the power plant as a necessary evil. The economies achieved by progressive managements points up the need for greater study of steam and power situations within individual plants. Here is one study method the author has found very effective.

By PEREZ OTIS LEWIN
Lewin Engineering Company

THE results from properly designed heat balance studies serve many very useful purposes. The fundamental objective of these studies in textile mills is to determine the heat and hot water requirements for each process in the range of productions from the treatment of raw materials through the finishing of yarns and fabrics for comparison to the available supply.

The Need for Study

Relatively few textile mill management keep themselves accurately informed in respect to the steam requirements, boiler capacity and their general condition in their mills. Their interests are somewhat naturally centered in the textile production methods employed and the equipment and materials used in the production of yarns and fabrics. There is an unfortunate tendency in the textile industry to consider steam boilers and power plants a necessary evil. Modernization or improvement of boiler and power facilities in many textile plants is not given serious consideration until the losses in production resulting from breakdowns and excessive worn parts replacement focuses management's attention to the fact that something of a corrective nature must be done. The economies which have been achieved by progressive managements have also focused general attention to the need for greater study of the steam and power situations and one of the first steps in that direction is to establish actual facts in respect to the current demands for steam.

The initial steps call for conducting an extensive fact finding survey of both steam and power usage broken down in three main divisions; namely, power, steam and hot water.

The study must determine the connected horsepower and the maximum demand created at peak production

* Presented at the Annual Meeting of the ASME, New York, N. Y., Nov. 26–30, 1956.

and relate this finding to the power capacity available either in generated or transformer capacity if purchased. If the power is purchased, the problem will resolve itself into concentration of attention to maintaining as low a demand as possible to insure taking full advantage of the lowest rate per KW.

If the power is generated by turbine-driven generators, the study should be made of the steam and water requirements to determine if the turbine is designed and operated to produce power at maximum efficiency.

The steam requirements for the various processes vary considerably with different types of textile mills. All woolen and worsted mills require large quantities of steam at various pressures. Some of these are for heating water for scouring wool, for washing and scouring woven cloth, for piece, stock and yarn dyeing and neutralizing. Steam is also used at low pressure for stock, yarn, piece and top dyeing and for drying the product of these processes. The drying comprises carbonizers, tenters, stock, top and yarn dryers. The low pressure demand also includes building heating. In cotton spinning and weaving mills process steam demand is very low. In cotton dyeing, printing and finishing the requirements are somewhat like that for woolens.

The Value of Heat Balance Studies

A heat balance study readily establishes the overall consumption of steam from its source, either the boilers or at the extraction point of a turbine, and answers the question as to the efficiency of the heat exchanger being supplied with the steam. It also establishes the pounds of steam used per pound of cloth, yarn or stock being processed. The effectiveness of all automatic controls and the thoroughness of inspection given them will also be uncovered by a formal study.

There are naturally several reasonably well-established methods of approach to the study of existing steam systems and usages. The method being described has been progressively developed from successful experiences in re-establishing efficient and economical operations in several steam and power plants in the textile industry.

A Suggested Method

A flow diagram of the Btu utilizations, starting at the boiler outlet, extending through to every process, will when completed, provide an easily understood accounting of the heat actually utilized in the various manufacturing processes as well as the amount of heat lost through inefficient heat exchangers or careless operation of the equipment. For instance, a cloth dryer cannot be expected to operate efficiently if the traps on the heating coils are not working properly, or if the screens in the sections of the dryer are filled up with lint, as well as the many other items that are often neglected. The study and diagram will disclose such information.

The first phase of a study might have to be done by the slow process of weighing the condensate from the separate sections of each unit in the event there was a lack of adequate steam flow meters on the steam lines, which is very often the case.

After the quantities of steam used in each section, as well as the definite check on the pressure drop through each piece of equipment, has been determined, the Btu or steam requirement can be readily established for each particular process. Their future value in respect to standardization will be dependent on all parts of the heat exchanging unit being kept clean and in good operating condition. The importance of keeping these records will readily become apparent, and continuing records of the amounts used for various weights and blends of goods will provide a valuable reference file. The installation of a steam flow meter, properly sized for the particular service for which it is to be used, will provide a means to establish desirable records.

Hot water is used as stated earlier for various processes. The amounts of hot water and the temperature requirements are a very important point to be considered in an overall heat balance study. For instance, water to be heated from an average temperature of 50 F to 120 F requires a 70 Btu input for every pound of water heated. This heat input to the water can be supplied as steam through a closed heater, from an open steam line into the water itself, or from the exhaust of a turbine into a condenser, heating the water as the steam is being condensed.

A steam flow diagram is just as important as the flow diagram of the stock throughout the manufacturing process. As textile production increases, so does the demand for power and steam. Many times, additional manufacturing equipment is purchased and installed and no thought given to whether or not there is sufficient capacity in the boilers or steam lines to meet any increased demand until after the equipment is in operation. In fifteen of twenty plants recently surveyed, it was found that the boiler plants were operating at over 150 per cent of rating and in some cases as high as 250 per cent all of which resulted in low boiler efficiency and excessive boiler maintenance.

One case in point was the designing of a new power plant to replace obsolete boilers and engines. Instructions were given to supply boiler and generating capacities of a definite size for maximum production based upon the present use and normally expected increases. After completing a heat balance study, an entirely different picture was developed resulting in substantially different specifications of requirements and economy in costs.

Specific Examples Cited

For the purpose of illustrating the value of flow diagrams, copies of charts of studies No. B-120 and C-120 have been prepared and made a part of this paper. They indicate the heat distribution in the form of high pressure steam, low pressure steam, and hot water used in the complete manufacturing processes of an existing plant recently studied.

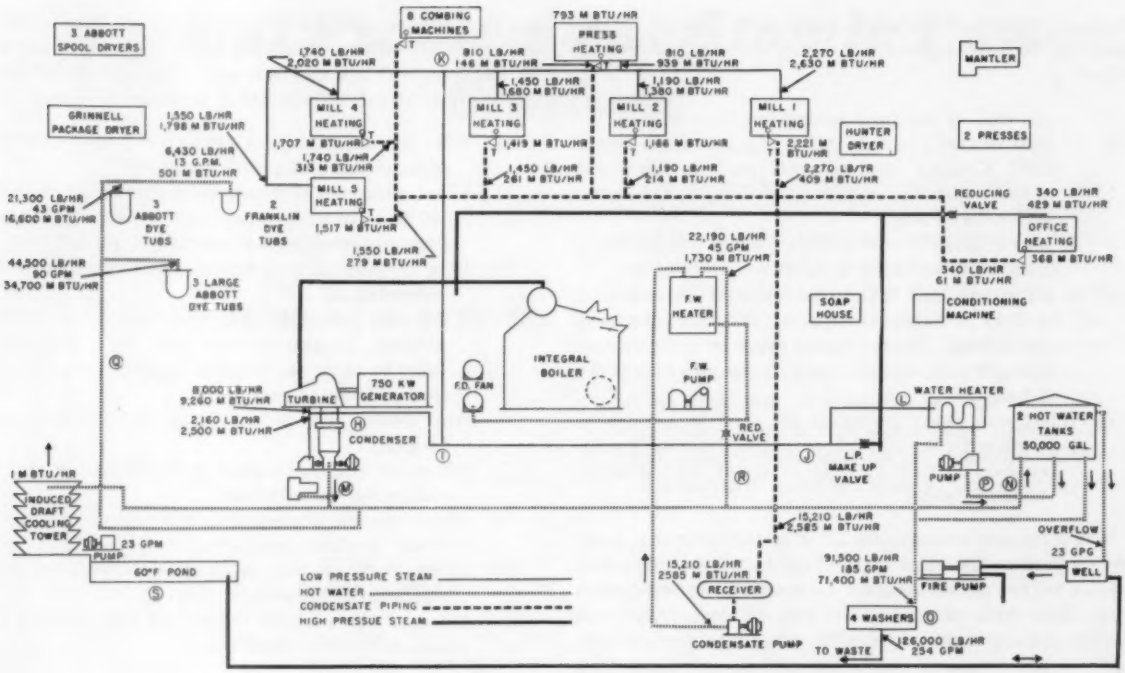
In order that the process of study and the results may be readily understood, the principal points of service have been lettered on the charts, and their relative distributions are being described in the following.

Study No. B-120

(A) indicates the steam outlet from the boiler.

(B) indicates the amount of steam required for the turbine generator and turbine driven condenser pump together with the air rejector on the condenser.

(C) shows the steam required to drive two of the boiler auxiliaries, i.e., the turbine driven



FLOW DIAGRAM, FULL OPERATING LOAD — MAXIMUM HEATING
STUDY No. C-120

Fig. 2.—Low pressure steam and hot water flows for a typical textile plant can be depicted in a heat balance fashion

forced draft fan, and the turbine driven boiler feed water pump.

(D) is the steam required for a dryer, a mangle, and two presses.

(E) is the steam required for eight wool combing machines.

(F) is the steam required for the dyeing and drying processes of the yarn, broken down as illustrated.

(G) is the steam used for the various other miscellaneous processes as indicated, but not considered a part of this heat cycle study. On the high pressure flow diagram, the high and low pressure condensate as shown are connected into a common receiver and pumped into the boiler feed water heater, where it is again returned to the boiler as feed water.

Study C-120

As in the preceding study, alphabetical identifications are being used in the following explanations of the process flow.

(H) treats with the steam that is extracted from the turbine generator at a fixed pre-determined pressure. The same is true of the exhaust steam from the turbine which drives the condenser used for heating and processes branching out from (I) to (J) and (K), i.e., (J) being the amount used to heat water at the closed heater at (L).

(K) indicates the amount used for all the mill heating.

(M) indicates the starting of the hot water distribution from the condenser and the after cooler of the air ejector. It continues to (N) where the water is stored in two hot water tanks located high enough to give sufficient head for distribution by gravity to the various uses at (0) and (Q).

The supplemental hot water heating unit, (P), is supplied by steam from the high pressure line through a reducing valve for emergency use.

The connection marked (R) is installed in the hot water line to supply make up to the boiler feed water heater.

The overflow from the hot water tank marked (S), shows the connection to the cooling pond, where surplus water can be cooled for reuse instead of being wasted. In this particular plant, all city water was used for processing.

As soon as the steam requirements for manufacturing have been established and all of the quantities determined for the power, auxiliary steam and water, one of the next important steps in the study is to analyze the facilities in the power plant.

A heat balance study of a power plant requires considerable time to conduct tests on the boilers to establish the efficiency being maintained over the complete range and at what rating or capacity they are being operated. It is necessary to determine the maximum efficiency maintained, the size, type and number of boilers being used, their age, condition and allowable pressure permitted by the insurance company. This phase of a study is time consuming and involves a sub-

stantial amount of technical know-how. Some of the items to be investigated are being referred to in the following:

a) Is oil, coal or gas used as fuel?
b) If coal is used, how is it burned, by hand firing, hand shaking grates, underfeed or overfeed stokers, spreader stokers, traveling chain grate, or powdered coal?
c) What methods of coal conveying and ash handling equipment are used if any?
d) If oil is used for fuel, what type of burners and method of firing is used, i.e., flat flame burners on natural draft, burner registers on forced draft, or any one of a half dozen different types of burners?
e) What provisions are made for dual fuels such as powdered coal and oil, or gas and oil, or a combination burner that is designed for either of the three fuels?

The foregoing summarizes a few of the facts that must be resolved at the start of the heat balance study, as it relates to the power plant. In many instances power plant heat balance studies are treated separately from manufacturing studies especially when the former happens to be of greater magnitude and supplies power for more than one mill.

Analysis of the data collected in the study provides investigating engineers and management with the information necessary to intelligently correct substandard conditions, improve facilities or replace in part or full such existing units as are necessary to attain up-to-date competitive steam and power plant operations in integrated textile operations and in any industrial activity.

As indicated earlier, studies of steam facilities can serve a large range of purposes. Studies reported in this field uncover conditions quite out of line with those which exist in the equipment and practices related to the industrial activity which depends to a reasonable extent on the steam and power being supplied. A few of the points of interest uncovered by the studies when put before management in textile mills have opened their eyes to economies of which they had no previous knowledge. Some of these points are being outlined briefly in the following. They can serve as focal points for discussions of heat balance studies at this time if desired.

1) Why has management neglected proper control of its steam and power facilities?
2) What is the cost of steam and power as generated?
3) How do current costs compare with the lowest costs obtainable from existing facilities?
4) How do current or potential costs compare with competition?
5) What cost reductions can be achieved from more modern equipment and how long would it take to amortize needed capital investments from calculated savings?
6) Are steam and power costs being calculated properly?
7) What are the by-product possibilities for steam and power distribution?
8) What are the economies obtainable from automatic controls, meters and recordings?
9) What part of overall manufacturing costs is made up of steam and power?
10) What is the plan of depreciation in respect to steam and power equipment?

Conclusion

One of the difficulties directly associated with creating a greater appreciation of the importance of steam and power facilities and operations is the erroneous opinion that it is a highly technical subject not easily understood by that part of management which deals with production of textiles. Actually steam and power management constitutes just another division of production and should be accepted as a part of plantwide operations.

If policy forming management would accept its steam and power division of activity on the same basis as manufacturing or selling and organize proper controls of a parallel nature, the success of its overall operations could not help being far better than would exist if these activities were to be considered as necessary evils.

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Thermal Problems of Atomic Power Stations*

By C. E. LUNDGREN and C. SEIPPEL

Brown Boveri and Co., Ltd.

For the development and construction of atomic power stations the requirements of an efficient and economical thermal plant must be made to conform to the limitations imposed by the physical and technological requirements of a reactor. In this article thermal engineers express their views on these reciprocal effects and, as an example, demonstrate how interesting it is to perform the entire process of heat absorption as near as possible to the maximum temperature of the reactor.

THE heat economy of an atomic power station differs from that of an ordinary thermal plant in two important respects:

1. In the thermal plant the reaction products of the chemical combustion possess a significant mass and heat capacity. It is, therefore, necessary to cool them to a relatively low temperature (100–150°C) in order to keep the losses in the exhaust gases down to a tolerable level. The products of a nuclear reaction, in contrast, have so small a mass that their removal is not accompanied by the loss of any heat worth mentioning.

2. The upper temperature limit of the process is in both cases governed by the strength of the building materials. In the combustion plant the chemical and mechanical strengths are the deciding factors. A range of high-grade steels has been developed which, however, cannot be employed in an atomic plant without first studying the requirements of nuclear physics in addition to the chemical and mechanical properties. For example, neutrons must not be absorbed. Many materials decompose under the effect of radiation in a nuclear reactor. Therefore, it has been necessary to develop a technology of building materials for reactors. The maximum temperatures, experienced by both the active and the constructional materials, are well below those of a conventional thermal installation.

Thermal Efficiency

The thermal efficiency of a heat engine is not governed solely by the highest temperature attained. The cycle efficiency η_p, by which is understood the ideal thermal efficiency assuming no losses in the turbine (and feed pump), is the sum of the amounts of heat dQ supplied to the working medium multiplied by the associated degree of availability $\eta_c = 1 - T_0/T$, divided by the total heat supplied. Here T is the temperature of the medium at the point where it takes up the amount of heat dQ, and T_0 is the ambient temperature. This gives

$$\eta_P = \frac{1}{Q_{tot}} \int_0^{Q_{tot}} \left(1 - \frac{T_0}{T}\right) dQ$$

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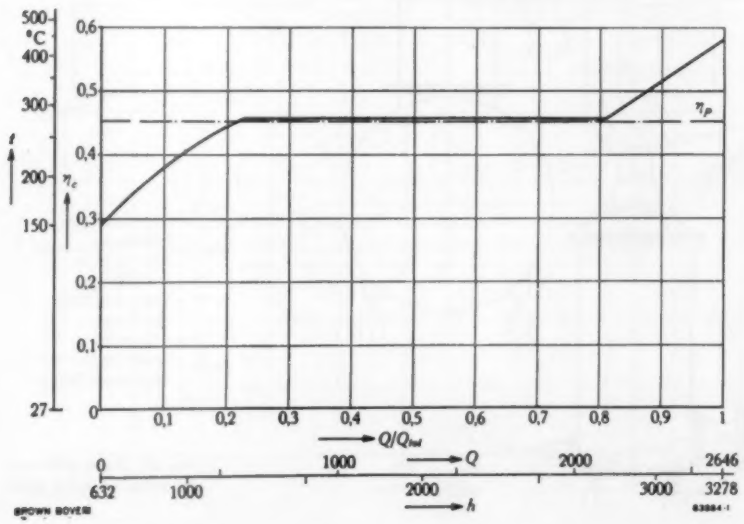


Q = The amount of heat successively supplied to generate superheated steam, in kJ/kg
Q_{tot} = Total amount of heat supplied in kJ/kg
h = Enthalpy in kJ/kg
t = Temperature in °C during generation of steam, as a function of the heat supplied
η_c = Degree of availability of the element of heat supplied dQ; according to Carnot = $1 - T_0/T$
η_P = Degree of availability of the total heat supplied Q_{tot} = cycle efficiency

Fig. 1.—Q-η_c diagram of the heat absorbed by steam

The above integral can be visualized in the form of an η_c-Q diagram (Fig. 1). The thermal efficiency at the terminals, obtained after deducting the losses in the turbine and feed-pump (15 per cent), in the generator (1.5 per cent), and those due to the non-reversibility of the condenser (4 per cent) and feed-water heaters (2.5 per cent), amounts to approximately 75–80 per cent of the cycle efficiency.[1]

Therefore, since, on the one hand, the upper temperature in the reactor is limited to quite a low value, and, on the other, there is no exhaust gas to be cooled, it is preferable to advance the entire heat absorption of the cycle as close as possible to the permissible temperature limit. This is performed most easily when the temperature is in the region of that of the boiling water. The maximum gain is obtained when heavy or ordinary water is evaporated in the reactor and expanded in a saturated-steam turbine. To do this the feed water is heated as high as possible by multistage bleeding. Water separation for the turbine must be effective, in which respect the bleeding points are very convenient.[2] If necessary a water separator can be incorporated in the expansion circuit. Fig. 2 illustrates the layout of a turbo-set of this kind.

When the temperature exceeds the evaporation range of the water, entirely new conditions arise, which will now be examined more closely. The same is true when the reactor is not designed to contain boiling water, but a carrier flows through it which gives up its heat to boiling water outside the reactor. The heat can no longer be taken up at a constant temperature level. The working medium itself, or the carrier, is heated as it flows through the reactor and operates with a temperature difference, which becomes greater as the quantity flowing and its specific heat diminish.

Let us now consider, as an example, one of the reactor systems at present being built in the U.S.A.[3] The same considerations apply in principle to other systems. Fig. 3 illustrates the layout of the plant. The heat is taken up by liquid sodium flowing in a closed circuit through the reactor and is employed to generate steam outside the reactor. Since the sodium becomes strongly radio-active, a secondary sodium circuit must be interposed between the primary and the steam circuits. Naturally the double heat transfer is accompanied by a corresponding drop in temperature, although this is not very large since the transfer rate using liquid metal is very good compared with other media.

In the plant in question the maximum temperature of the primary sodium circuit is 496 C, of the secondary circuit 479 C and of the steam 441 C. Let us now, ignoring the effect on the reactor, study a number of different steam cycles all of which have the same maximum live steam temperature, their data and cycle efficiencies being given in Table I. Fig. 4 shows the temperature t as a function of the amount of heat supplied Q.

Cycle Comparisons

The first cycle in Table I(56 bar at the turbine, 63 bar in the exchanger) can obtain its heat from a sodium cur-

[1] C. Seippel: "The Energy Economy of Steam Power Plants." *Brown Boveri Rev.* 1950, Vol. 37, No. 10, pp. 342–56.

[2] J. Lalive d'Epinay and W. Luthi: "The Steam Turbine in the Atomic Power Station." *Brown Boveri Rev.* 1954, Vol. 41, No. 3/4, pp. 101–7.

[3] C. Starr: Sodium Graphite Reactor, 75000 Electrical Kilowatt Power Plant. Report No. P/493 to Atomic Energy Conference, Geneva 1955.

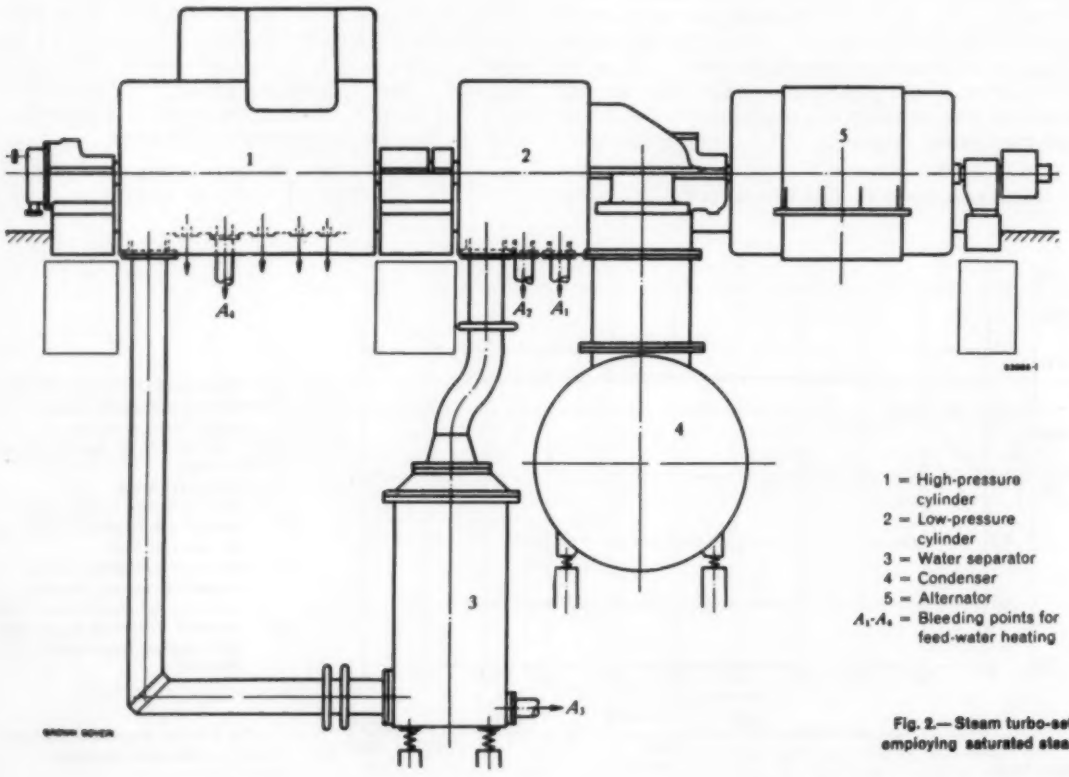
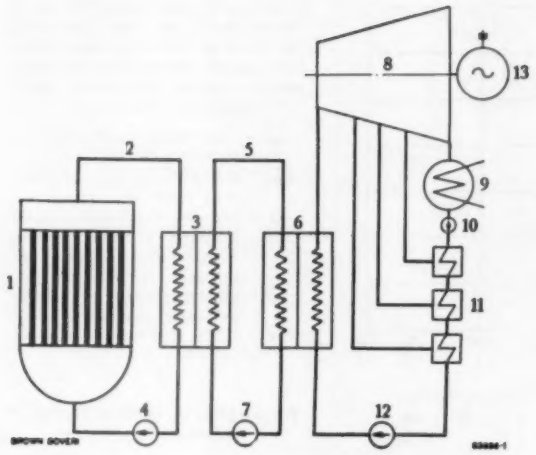


Fig. 2.— Steam turbo-set employing saturated steam



1 = Reactor
2 = Primary sodium circuit
3 = Primary exchanger
4 = Primary sodium pump
5 = Secondary sodium circuit
6 = Secondary exchanger (steam generator)
7 = Secondary sodium pump
8 = Turbine
9 = Condenser
10 = Condensate pump
11 = Feed-water heating equipment
12 = Feed pump
13 = Alternator

Fig. 3.—Atomic power plant employing sodium (or sodium-potassium solution) as heat carrier

rent which gives up heat between the limits 243 C and 479 C. For the heat transfer, there is then an average or effective temperature drop of 60 degree C available, this effective mean $\bar{\Delta}$ being calculated in the following manner, assuming a constant heat transfer coefficient k:

$$kA = \int_0^{Q_{tot}} \frac{dQ}{\Delta} = \frac{Q_{tot}}{\bar{\Delta}}, \text{ hence } \frac{1}{\bar{\Delta}} = \frac{1}{Q_{tot}} \int_0^{Q_{tot}} \frac{dQ}{\Delta}$$

where A is the transferring surface area and Δ is the temperature difference expressed as a function of Q. If the steam pressure is raised and the sodium temperature kept the same, the temperature drop is reduced. In the second and third cycles (93 and 140 bar) the temperature lines of the steam and the sodium would cross and exchange of heat would no longer be possible. The temperature of the sodium must therefore be raised. Having used the same maximum steam temperature in all three cycles, let us also leave unchanged the maximum sodium temperature, i.e. the temperature at the outlet from the first heat exchanger and, indirectly, at the reactor outlet, but increase the temperature at the intake to the exchanger (Fig. 4). The latter can be raised, so that the effective temperature drop remains say 60 degrees C or assumes another given value within certain limits. The effect of this temperature rise on the reactor will be examined later. Fig. 5 demonstrates the relationship between the lower temperature limit of the sodium (assuming a fixed upper limit) and the effective temperature drop in the heat exchanger for the steam data selected. The diagram also indicates how the rate of flow of the sodium changes with this temperature.

From this curve it can be seen that a temperature drop of 60 degrees C at a supercritical pressure of 320 bar can only be achieved when the rate of flow is more than trebled. For this reason 60 degrees and 30 degrees C have been selected as typical temperature drops; the latter requires double the surface area. For these drops the thermal efficiency of the cycle can be plotted against the sodium temperature at the inlet to the second heat exchanger or at the reactor inlet (Fig. 6). From the diagram it is possible to read off direct the gain obtained by raising this temperature.

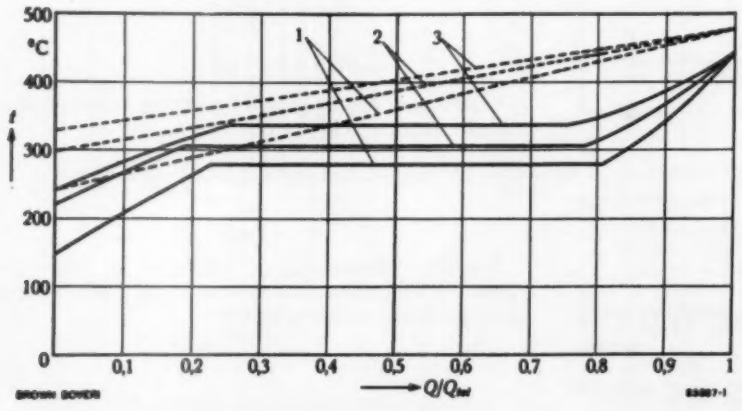
Let us now examine the effect on the reactor of the above-mentioned temperature changes in the sodium. Assuming an invariable amount of heat, the circulation of sodium in the secondary circuit must be increased inversely proportional to the reduced temperature difference, since the specific heat remains almost constant.[4]

TABLE I—DATA FOR CYCLE COMPARISONS, FIG. 4

No.	Steam pressure: In heat exchanger bar	Steam pressure: before turbine bar	Steam temperature before turbine, °C.	Feed-water temperature, °C.	Cycle efficiency
1	63	56	441	149	0.452
2	93	87	441	220	0.485
3	140	130	441	240	0.507

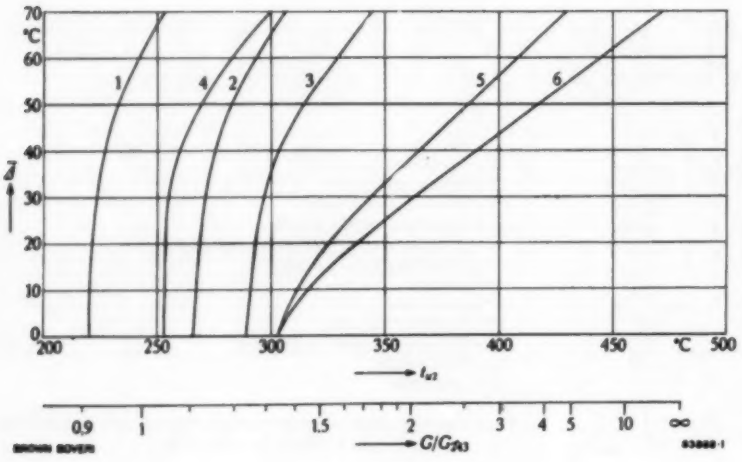
1 bar = 1.02 kg/cm² = 14.5 lb/in²

[4] Liquid-Metals Handbook; U. S. Govt. Printing Office, Washington, 1952.



t = Temperature
Q = Successively supplied heat
Q_{tot} = Total heat supplied
1, 2, 3 = Cycles as in Table I
—— = Temperature line of the steam
—— = Temperature line of the secondary sodium for an effective temperature drop $\bar{\Delta}$ in the secondary exchanger of 60 °C

Fig. 4.—Temperature diagram of the secondary heat exchanger



If, for a given steam cycle (1 to 6 as in Tables I and II), the lower temperature limit is varied while the upper limit is kept constant, the effective mean temperature drop for heat transfer varies according to these curves.

t_{s2} = Lower temperature limit of secondary sodium

G_{243} = Amount of sodium in circulation at t_{s2} = 243 °C

G = The amount of sodium to be circulated at other temperatures to obtain the same heat output

$\bar{\Delta}$ = Effective temperature drop in secondary exchanger

1 to 6 = Cycles as in Tables I and II

Fig. 5.—Effective temperature drop in the secondary exchanger

Let us first assume that the primary circulation of sodium is changed in the same manner and the temperature drop in the exchanger between the two liquid metal circuits remains the same. The temperature lines of the primary and secondary sodium, as functions of the heat transferred, undergo a parallel displacement (Fig. 7, *a* and *b*). Thus the sodium temperature at the reactor outlet remains unchanged under the assumed conditions. At the outlet of the active uranium core the temperature also remains the same, and only at the cold inlet side does it rise corresponding to the increased sodium temperature. But the uranium is not hottest at the outlet; the maximum temperature is experienced in the interior of the core, and this maximum, the only factor that matters, does not remain entirely unaffected by the changed conditions, as will now be demonstrated.

The development of heat is not equally intensive throughout the entire core; it is strongest in the middle and decreases toward the surface. When the active core is not bounded top and bottom by a neutron reflector (this can on the other hand be round the circumference), the distribution curve of the heat intensity along a uranium rod is approximately half a sine wave. This is computed from the laws of neutron diffusion (Fig. 8). The temperature of the sodium along the reactor channel, corresponding to the integral of the sine rule, varies according to a cosine rule. This temperature is superimposed on the temperature drop from the middle to the surface of the active uranium element and the drop between the surface and the sodium, both drops being proportional to the heat intensity and therefore sinusoidal (Fig. 8*b*). Hence, the temperature inside the uranium is the sum of a sine and a cosine function. In order to retain the maximum temperature, the amplitudes of these two harmonic functions may be added vectorially. In this way we obtain

$$t_{max} = t_{m,\,Na} + \sqrt{\left(\frac{\Delta t_{Na}}{2}\right)^2 + (\delta t)^2}$$

in which

$t_{m,\,Na}$ = mean temperature of sodium

Δt_{Na} = temperature difference of sodium

δt = maximum temperature difference between the inside of the uranium and the sodium

The value δt was computed in the following manner: The heat transfer from the surface to the sodium takes place according to[5]

$$Nu = 7 + 0.025 Pe^{0.8}$$

$$\text{with } a = 6.75 \frac{W}{\text{cm}^2\ °\text{C}}$$

Conduction of the heat through the canning containing the uranium is defined by

$$\frac{1}{\sum \frac{\delta}{\lambda}} = 4.65 \frac{\text{W}}{\text{cm}^2\ °\text{C}}$$

For the cylindrical rods employed in the example chosen, if heat generation were uniform, the temperature drop inside the uranium would be

$$t_c - t_0 = \frac{q_0 \cdot a}{2\lambda}$$

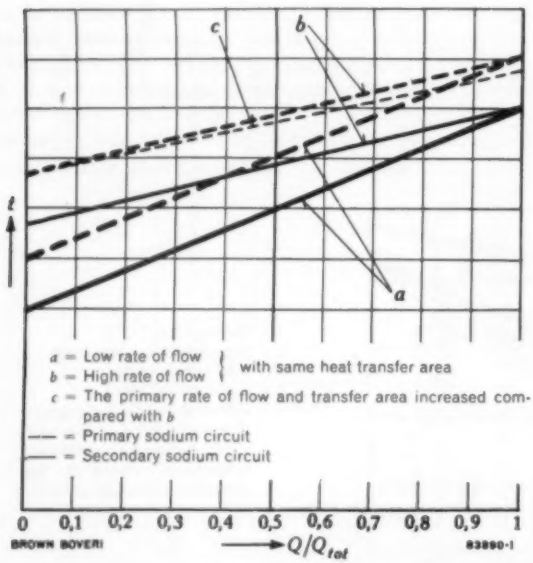
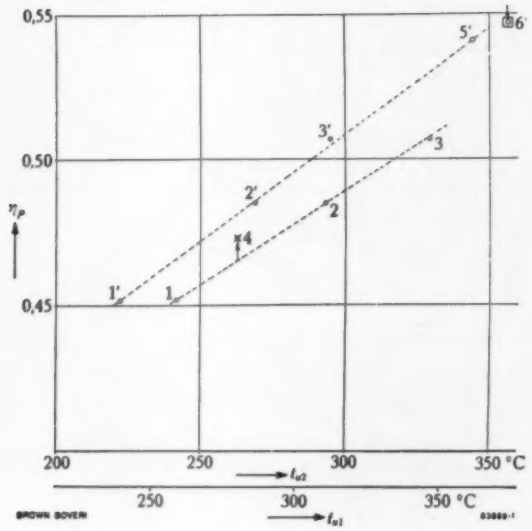


Fig. 7.—Temperatures of the primary and secondary sodium circuits

[5] R. N. Lyon: Chem. Eng. Prog. 1951, Vol. 47, p. 75.



The diagram shows the cycle efficiency η_p of the various steam cycles 1 to 6 in Tables I and II as a function of the lower temperature of the sodium.

Points 1, 2, 3, 4 are at $\bar{\Delta} = 60$ °C
Points 1', 2', 3', 5', 6' are at $\bar{\Delta} = 30$ °C

where Δ is the effective temperature drop in the secondary exchanger

t_{a1} = Lower temperature of primary sodium
t_{a2} = Lower temperature of secondary sodium

Fig. 6.—Effect of the lower temperature limit of the sodium on the efficiency of the cycle

where

t_c = temperature at the center
t_0 = temperature at the surface
q_a = flow of heat at the surface
λ = thermal conductivity
a = radius of the cylinder

Taking the actual distribution of heat generation, we obtain the smaller value

$$t_c - t_0 = \frac{q_a}{\chi\lambda} \cdot \frac{I_0(\chi a) - 1}{I_1(\chi a)}$$

in which

$I_0(\chi \cdot a)$ is the modified Bessel function of 1st kind, 0 order[6]

$I_1(\chi \cdot a)$ is the modified Bessel function of 1st kind, 1st order[6]

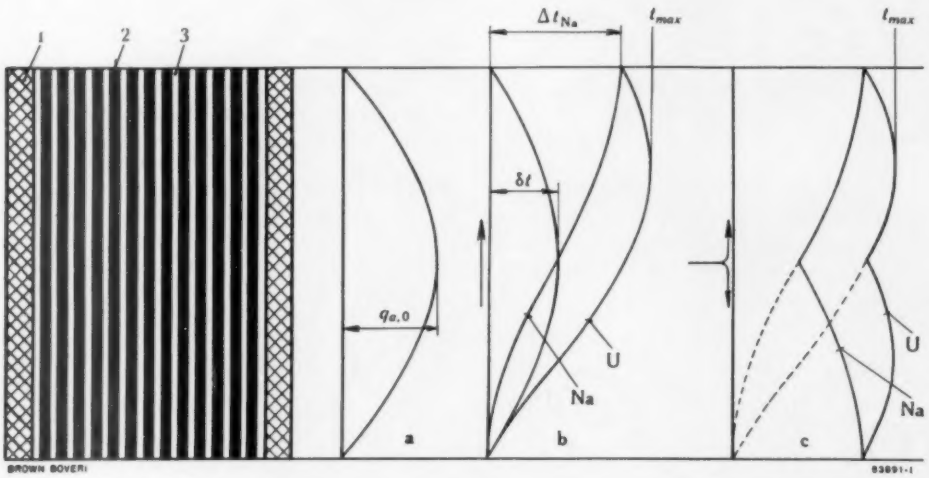
χ is the reciprocal diffusion length of thermal neutron in uranium

For the maximum heat flow of 110w/cm² at the middle of the central rod we obtain

$$\delta t = 124°C$$

With this value the peak values of the uranium temperature are obtained as illustrated in Fig. 9 in relation to the temperature of the sodium entering the reactor. If this temperature is now increased by say 100 degrees C or

[6] See, for instance, Kármán and Biot: Mathematical Methods in Engineering. McGraw-Hill, New York 1940.



1 = Reflector
2 = Rod
3 = Cooling channel
a = Heat intensity
b = Single flow
c = Divided flow

$q_{a,0}$ = Peak value of heat intensity
δt = Maximum temperature difference between middle of uranium and sodium
t_{Na} = Temperature range of sodium
t_{max} = Maximum rod temperature
U = Uranium
Na = Sodium

Fig. 8.—Illustrating the heat intensity and the temperatures of uranium and sodium along the channels of a reactor

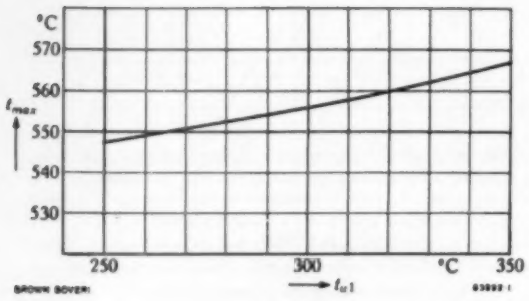


Fig. 9.—Maximum uranium temperature t_{max} as a function of the sodium temperature at the reactor inlet

somewhat less than half the total difference, which for the plant makes an improvement of about 14 per cent possible, or a gain of approximately 11 Mw of electrical energy, the peak value rises by roughly 20 degrees C.

This increase might, perhaps, be inadmissible, and we must first examine by what means it can be diminished. It was tacitly assumed that the temperature at the outlet of the reactor channels would be uniform. Since the heat generation in the middle of the core is greater than at the periphery, the flow of coolant has to be restricted in the center channels. But as this cannot be performed with any great accuracy, it is estimated that the maximum temperature ought to be about 14 degrees C above the mean value when the temperature difference of the sodium is 236 degrees C. The ratio of this excess to the temperature difference should remain approximately constant, therefore in the above case it falls to 8 degrees C. By enlarging the primary heat exchanger by 18 per cent and increasing the primary sodium circulation by 2 per cent, a further reduction in the temperature difference from 17 to 12 degrees C can be effected (see Fig. 7, *c*). Thus in these two ways it is possible to cut down the 20 degrees C rise by nearly half. Should it still be excessive, the circulation temperature could be reduced by 9 degrees C, but only by sacrificing about 1.5 of the 14 per cent which can otherwise be gained.

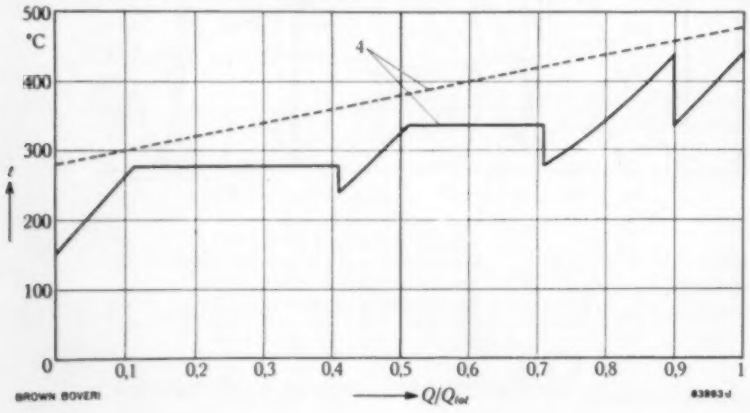
The Flow of Sodium

Reduction of the temperature difference of the sodium with its thermodynamic advantages is only possible, as we have already seen, by increasing the rate of flow. Let us consider the flow of sodium:

(a) through the reactor
(b) through the heat exchanger
(c) through the connecting pipes

First let us examine to what extent the cooling current can be forced through a completely unchanged reactor core by increasing the power of the pump. In the plant mentioned previously which has a terminal output of 80 Mw, with the data given for the first example in Table I, the pressure drop is shown as 0.42 bar. When the rate of flow is 833 kg/s, the density 830 kg/m³ and the pump efficiency 60 per cent, about 70 kw will be needed to overcome resistance to the flow within the core. One gains the impression that this value could be considerably increased without affecting the economy and without causing inadmissible pressures. The increased speed of flow increases the transfer of heat from the wall to the liquid metal, although to no great extent, and reduces the maximum temperature of the uranium. Raising the temperature by 100 degrees C (as in the example quoted in the last section) and correspondingly increasing the quantity of sodium by a factor of 1.74 enables the heat transfer coefficient to be raised by 18 per cent and the uranium maximum temperature reduced 2.5 degrees C.

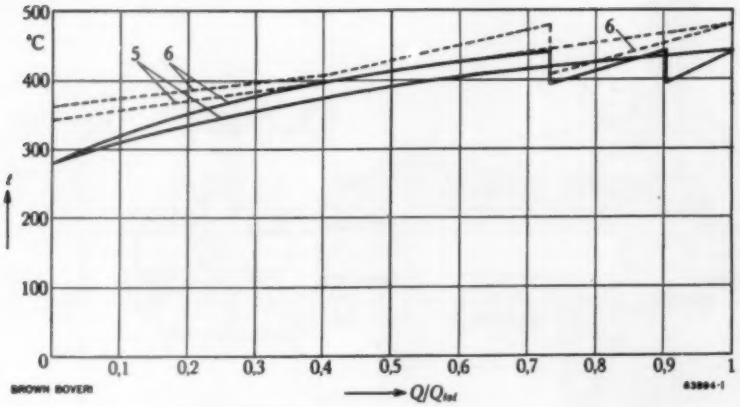
From the thermal point of view, with an increased sodium flow one would tend to increase the cross-section of the cooling channels in the reactor core; for instance, either by increasing the actual dimensions or by providing more channels: the length of the channels can then be correspondingly diminished. But we must first remember that altering the proportions of the reactor will affect the nuclear physical properties which must then be investigated afresh. It would be preferable not to deviate for reasons connected with the heat transfer from those reactor proportions which are most favourable from the nuclear physics aspect unless absolutely forced to do so. It would be most interesting, although it would also involve skilful design, to introduce the coolant half-way up the reactor core and divide the flow between the top and bottom halves. The rate of flow of sodium could then be doubled compared with the undirectional flow system and the temperature difference halved (as may be seen in Fig. 8*c*) without raising the maximum temperature of the uranium or increasing the load on the pump. In principle, it is correct for the coolant inlet to the reactor core to be located in the regions where the heat generation is most intense. In gas-cooled reactors this fundamental principle has, as far as is known, already been figured.



The staggered-pressure cycle 4 (Table II) is a combination of cycles 1 and 3 (Table I).

——— = Temperature line of the steam
– – – – = Temperature line of the secondary sodium for $\bar{\vartheta} = 60$ °C

Fig. 10.—*Q-t* diagram of a staggered-pressure plant



Cycle 5 without, cycle 6 with two-stage reheat as in Table II

——— = Temperature line of the steam

– – – = Temperature line of the secondary sodium for $\bar{\Delta} = 30°C$

Fig. 11.—Q-t diagram of supercritical steam cycles

Raising the lower limiting temperature of the sodium does not necessitate the transfer surface being enlarged in the primary heat exchanger, provided the temperature difference between the circuits remains the same (Fig. 7, *a* and *b*), but it is necessary to spread this surface over a larger number of shorter channels. The energy dissipated by friction inside this exchanger remains unchanged. The size and energy dissipation of the second heat exchanger depends on its mean temperature drop, shown in Fig. 6 as parameter. Naturally, its construction is also very dependent on the steam pressure. A sensible solution would be to increase the sodium connecting pipe in proportion to the rate of flow, but in such a manner that the pressure drop remains unaltered. Taking everything into consideration, it is estimated that to increase the rate of flow by a factor of 1.74 (corresponding to a temperature rise of 100 degrees C) in the 80-Mw plant, the power supplied to the pumps must be increased from 400 to 1000 kw which, in view of the effective gain in output of approximately 9000 kw, is quite acceptable.

Supercritical Steam Cycles

The above investigations into ways and means of improving the efficiency of an atomic power plant have produced a positive result without the maximum temperature having to be raised. By increasing the steam pressure and feed-water temperature the heat diagram is "filled out" and more nearly approaches the Carnot cycle.

Let us now take two further steps in the direction already commenced and examine the properties of atomic power plants:

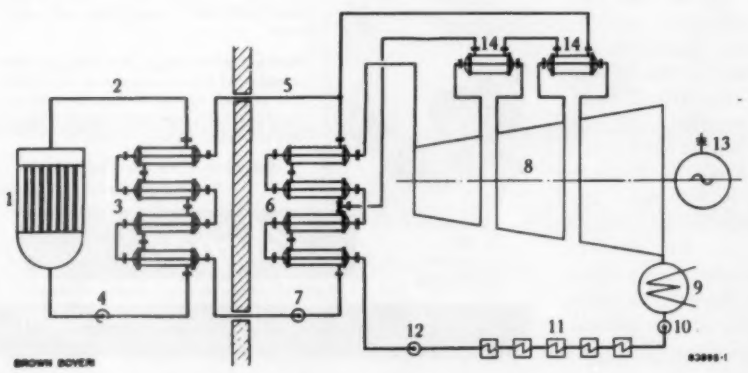
(a) with two staggered steam pressures
(b) with supercritical steam pressure, with or without double reheat (Table II).

Fig. 10 shows the temperature diagram of the staggered-pressure plant and makes its advantages obvious. With the slope of the sodium line as given, the stepped temperature curve of the two-pressure plant approaches nearer to it than does the curve of the single-pressure plant. It approaches nearer to the ideal of a counterflow heat-exchanger. It must, however, be admitted that the complication in the installation of the heat exchangers, piping and turbine is considerable, whereas the gain is only moderate, as illustrated by point 4 in Fig. 6 (47.3 per cent, as compared with 46.5 per cent at a lower secondary sodium temperature of 263 C). That multi-pressure plants are nevertheless under construction, is due to the fact that gaseous heat carriers need wider temperature ranges than other media and necessitate the employment of multi-pressure cycles. In another case, two pressures

TABLE II—DATA LISTING FOR CYCLE COMPARISONS

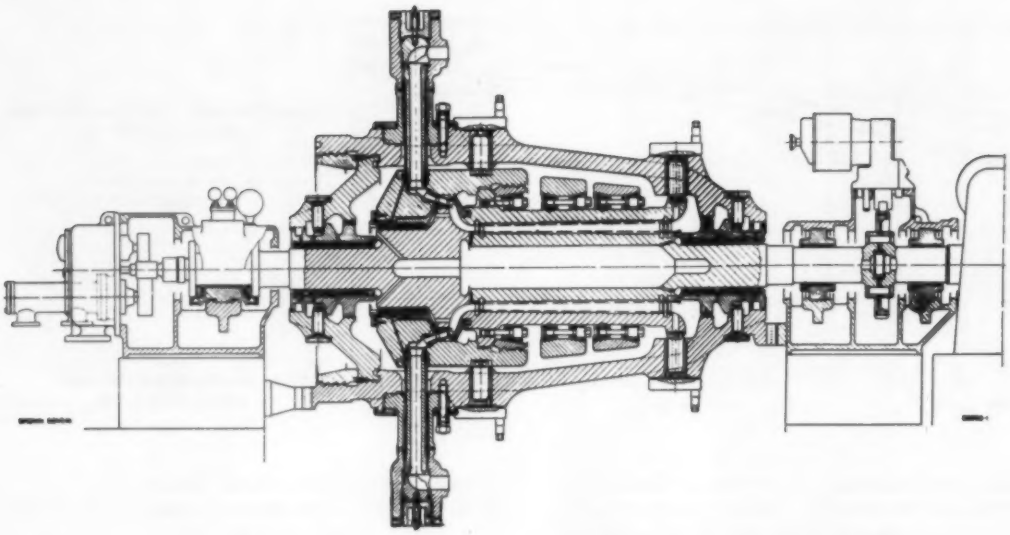
No.	Steam pressure: In heat exchanger bar	Steam pressure: Before turbine bar	Steam temperature before turbine, °C.	Feed-water temperature, °C.	Cycle efficiency
4	140 / 63	130 / 56	441 / 441	240 / 149	0.473*
5	320	300	441	280	0.541
6	320	300	441	280	0.547†

* Equal quantities in high- and low-pressure cycle.
† 1st reheat: pressure 230 bar, final temp. 441 C
2nd reheat: pressure 170 bar, final temp. 441 C.



1–13 = see Fig. 3
14 = Reheater

Fig. 12.—Schematic diagram of a plant with two reheaters heated by sodium



The turbine operates between the pressures 300 and 140 bar and, for live-steam temperatures up to 620 °C, is built of ferritic material (with the exception of the austenitic inlet devices)

Fig. 13.— Super-pressure turbine

are employed with the object of limiting the formation of steam bubbles in a boiling-water reactor.

The temperatures of certain types of present-day reactors, e.g. of that considered for the purpose of this article, already permit us to think in terms of supercritical steam pressures. This may appear somewhat venturesome at the moment, but the fundamental advantages offered by supercritical pressure are so great that it is bound to be adopted sooner or later. The main advantage, immediately obvious from Fig.11, is that the temperature-heat curve no longer has the horizontal section corresponding to evaporation. It is a much closer approach to that of the ideal counterflow heat-exchanger. Of course, the counterflow principle is realized even better with a gaseous medium. But the latter loses the important advantages of condensation in the low-temperature range, isothermal heat rejection in the condenser and the low power required by the feed pumps as compared with gas compression. Thus, the steam cycle with supercritical pressure combines the major advantages of the steam and gas cycles. As shown in Fig. 12, some of the sodium is diverted and used in the reheat stages which are not only needed to dry the steam but are also advantageous thermodynamically (in contrast to the installation employing saturated steam, described on pages 101–7 of the March/April 1954 issue of the Brown Boveri *Review*). The diverted sodium current can flow through the two reheaters in series or parallel. Fig. 13 illustrates the manner in which Brown Boveri have overcome the problems encountered in the design of a super-pressure turbine employing live steam at 300 bar. Investigations at present being undertaken into heat exchangers for supercritical pressure have not, so far, brought to light any insurmountable obstacles. This kind of heat exchanger may, perhaps, be even simpler than an evaporating exchanger operating at sub-critical pressure.

In conclusion, it is stressed that the figures quoted should by no means be treated as final, but be taken as an indication of the general relationship.

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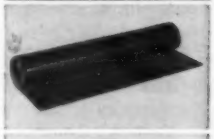

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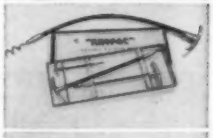

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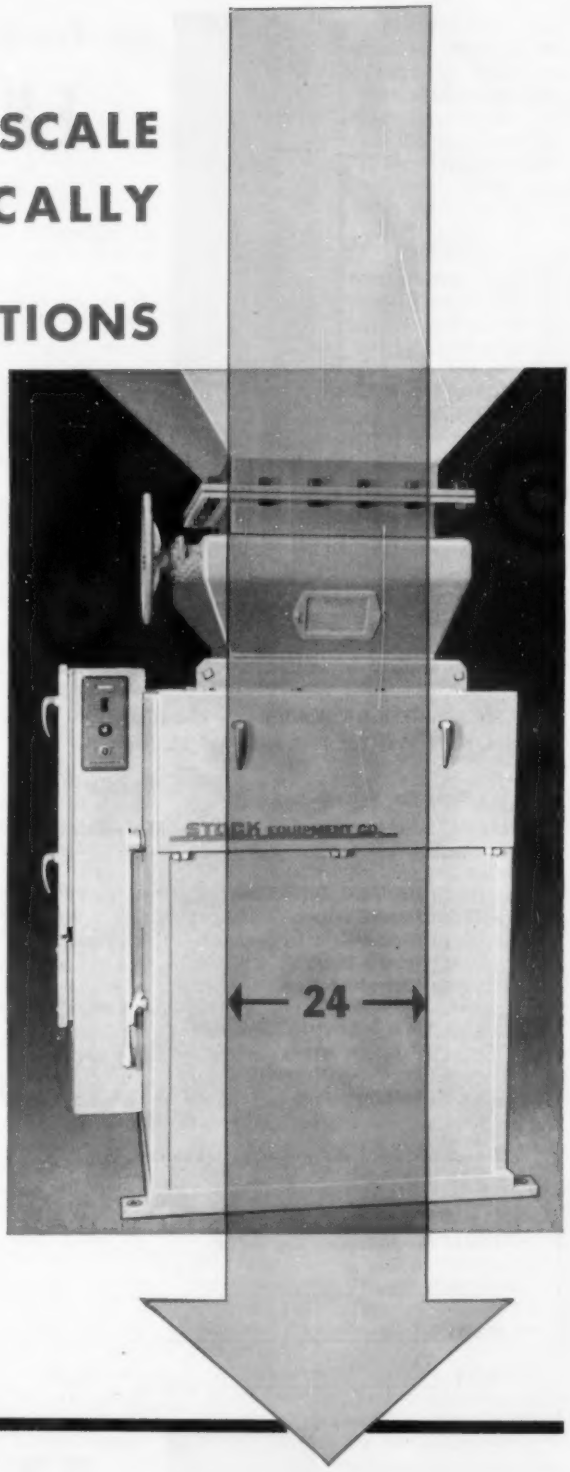

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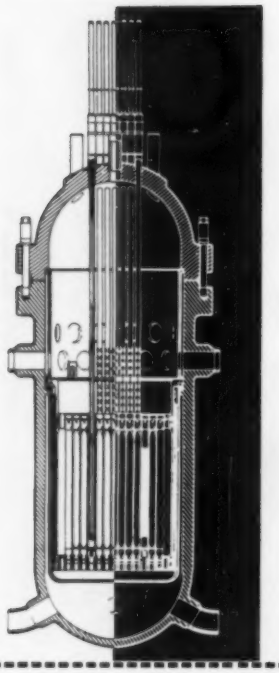

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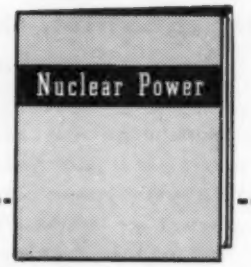

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The Engineer and the American Economy*

BY
John B. Rae†

AT no time in our history have the American people been so acutely aware of the engineer as they are today. He is a commodity in critically short supply, and we are all having this situation brought forcefully to our attention by a ceaseless torrent of data, ideas, appeals, and suggestions on what to do about it. Some of the proposals make sense—revamping our educational system to place more emphasis on mathematics and science and to direct more of our talented youth into technology. Some border on the hysterical, like the school of thought which advocates that engineers be restricted to purely technical functions and not allowed to fritter away their skills in such areas as management. Some appear to be concerned with a numerical contest between ourselves and the Russians, demanding that we get ahead in quantity without worrying about quality or the type of engineering skill that can contribute most to the needs of our own economy.

We can remember when the situation was radically different. Twenty years or so ago there seemed to be too many engineers and there were influential voices suggesting that scientific and technological progress had outrun man's moral and intellectual capacity to manage it. As a matter of fact, this point of view can still be found without looking too hard. So if you must worry, you can have your choice: we have too much technology and too many engineers, or we have not nearly enough.

Now we do not wish for one moment to suggest that everything is all right and that we have nothing whatever to worry about. We all know better. If we ever get into such a state of mind, where we do not feel any urge to be concerned about the possibility of improving the way we do things, then we will genuinely have a right to be worried. What we do wish to say is that the counsels of despair show both lack of faith in the vitality of a free society and a lack of understanding of the part that the engineer has played in American life.

A Look At Our History

Technical skill has been an important factor in American life from the beginning. From colonial times to the present there has been more work to do than there have been hands to do it, with a consequent premium on the methods of multiplying the productivity of human labor. This point can be illustrated most vividly by going back to the era when the United States was what is now politely termed an "underdeveloped area"—a stage in our history which did not end until at least the time of the Civil War. Our industrial system was embryonic, and technical education was almost non-existent. What do we find: the Erie Canal, 300 miles through a semi-wilderness, with hand labor and self-taught engineers; Eli Whitney and Simeon North working out the basic principles of mass production; McCormick and Hussey mechanizing agriculture; the list could be extended to indefinite length, but there is enough here to show what is meant.

The men who have had this kind of skill—it is a little difficult to decide when we can start calling them engineers—have normally been rated among the most valuable members of American society. More than that, we have always taken it for granted that the man who knew how to do something was also the proper person to go ahead and do it. This is a continuing tradition from the men mentioned through figures like Corliss and Westinghouse down to the present day, when men with engineering training constitute the largest single group of top-ranking executives in industry. This tradition stems from an emphasis on getting things done—a very natural one under American conditions—which meant that science and technology were expected to be put to practical use. More importance has been attached to knowing how something worked than to knowing why.

There are drawbacks to this attitude. It has resulted in less attention being given to pure research than is really desirable, so that basic discoveries are still more likely than not to originate elsewhere than in the United States. It also resulted for a long time in an excess of confidence in cut-and-try methods at the expense of systematic training. But the advantages clearly outweigh the disadvantages. Our technologists have never been isolated from the main stream of American life, segregated in their laboratories or behind their drawing boards and told to leave the decisions to their betters. They have been expected to share in the responsibility for applying their own skills, and their participation has contributed in no small degree to the fact that in the United States today the fruits of technology are more extensively employed and more widely distributed than anywhere else in the world.

The Value of Freedom

How has this condition been achieved? It would be nice to think that it is all due to our superior abilities or our intrinsic merits, but we know perfectly well that it isn't. Americans have no monopoly on talent, and we are not even sure that we are more virtuous and deserving than other people. In fact, in our own technological development we have drawn freely on others for both ideas and trained personnel—figures like Samuel Slater, John A. Roebling, Charles Steinmetz. One striking example is Anthony F. Lucas, born in Montenegro, educated in Austria, and first to tap the Spindletop oil field in Texas.

The essential ingredient in what we have achieved economically and technologically has been freedom. We have let ability find its own outlets. No one tells a young man that he must remain an engineer all his life.

Take the example of Paul W. Litchfield, an MIT graduate who has achieved some distinction. His decision to take a job in a rubber factory was his own—perhaps not completely voluntary, because he explains in his autobiography that he graduated during the depression and the rubber factory was the best thing he could get. It was a completely voluntary choice, however, that sent him to Akron in 1900 to work for the fledgling Goodyear company because he shared Frank Seiberling's belief that the manufacture of tires for horseless carriages was the most promising prospect in the industry. Was it a waste of engineering talent later on to put Mr. Litchfield at the head of the company?

There is one passage in this autobiography which I want to quote, since it points up very effectively the sharply increased participation of engineers in industrial management during the last half-century:

"Harvard men," says Mr. Litchfield, "used to say the Tech would turn out engineers, but that the nation would look to Harvard for the heads of business. Some of the men who were in school with me, however, got long all right, and I got a little satisfaction out of it as Alfred P. Sloan, class of '95, became head of General Motors, Gerard Swope, also '95, head of General Electric, and Irene du Pont, class of '97. was made head of that great company —Curiously enough, Sloan, Swope,

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* Prepared for delivery at the Third General Assembly, Engineers Joint Council, Hotel Statler, New York City, Jan. 17, 1957.

† Associate Professor of History, M. I. T. (currently Exchange Associate Professor of Social Studies, Case Institute of Technology).

du Pont and I eachbec ame president of our respective companies about the same time."

Admittedly this is one side of the picture. The other is that if we insist on letting people manage their own lives, there is unavoidably going to be a good deal of waste and inefficiency, and even inequity and injustice. Sometimes it seems that a more systematically planned and organized system ought to produce better results. The trouble with that is that we have now seen it tried. The planned society has turned out to be another name for a new form of human slavery—for tyranny and misery so grim that we have seen its victims in their desperation fight tanks with their bare hands. The road to the planned economy should be marked "Expressway to the concentration camp."

Preservation of Enterprise

Whatever its weakness, our way of doing things has produced a higher standard of living and a wider distribution of goods than has ever been experienced in the history of mankind, and we are prepared to argue that we come out reasonably well in the realm of non-material values. We do not believe that perfection can be attained by any human agency; we do believe the evidence of history to be convincingly clear that a system based on freedom of enterprise does more for the welfare of humanity than anything else.

The preservation and extension of this system is the great objective for which our technological skill should be organized and directed. What can the engineer contribute to this end? First, production: if there is to be wealth to distribute, it must first of all be produced. This may seem to be a needless truism, but it is frequently overlooked. The spectacular productivity of the American economy has been very largely a story of constant technological advance. If our economy is to remain productive, it will require a technology continually on the alert for better ways of doing things.

We hope that we will never again talk about slowing up or halting technological progress. That is the way to stagnation and decay. The ability of the engineer to harness the forces of nature is a talent given by God to be used for the benefit of mankind. It is the unfaithful servant who buries his talent in the ground.

Beyond production, policy making. A substantial share of responsibility for the management of American industry has habitually been given to the engineer and this share has been increasingly marked during the last half century. It is therefore no longer sufficient for an engineer to be just technically competent; he must be prepared also to make decisions on matters of business policy based on all the manifold factors involved in the conduct of modern industry. He has to realize, moreover, that these decisions affect more than the affairs of one company, or even an entire industry. They help to determine the shape of the economy in which we all live, so that it behooves the decision-makers to have a clear idea of the kind of economy they want.

For all of us, we take it for granted that this means an economy of free enterprise, but are we sure that we understand just what this term implies? To make such a system function is an inordinately difficult task. Our industrial economy is an infinitely complex delicately adjusted and rapidly changing organism whose management requires not only information but judgment and wisdom of a high order. When something goes wrong, there is always the temptation to take the easy way out and invoke the power of government to apply a remedy. Now most of us will accept the need for public authority to regulate the economy so as to prevent the exploitation of the weak by the greedy and to give some protection against the hazards of industrial society to those who are not in a position to take care of themselves. The itch to regulate, however, can very easily get out of control, and past experience offers plenty of evidence to show that when it does, economic progress is killed by slow strangulation.

The Engineer's Challenge

Here is the challenge to the American engineer. You have a vital role in the operation of our national economy, both as technical experts and as administrators. Can you fill this role so as to maintain a healthy, vigorous freedom of enterprise—and to demonstrate that a free-enterprise system will not only function under modern industrial conditions but will function better than anything else that might be attempted?

This is a large order, but not impossible. For the spirit in which the effort ought to be made let us go back into our past to another group of people who were contemplating a momentous undertaking—the Pilgrims. Their historian and governor, William Bradford, tells of all the objections and fears that were expressed when it was proposed that they should seek a new home in the American wilderness, conceded that most of them were well founded, and then goes on:

"It was answered, that all great and honorable actions are accompanied with great difficulties and must be both enterprised and overcome with answerable courages. It was granted the dangers were great, but not desperate. The difficulties were many, but not invincible. For though there were many of them likely, yet they were not certain; it might be sundry of the things feared might never befall; others by provident care and the use of good means might in a measure be prevented; and all of them, through the help of God, by fortitude and patience, might either be borne or overcome. True it was that such attempts were not to be made and undertaken without good ground and reason; not rashly or lightly as many have done. But their condition was not ordinary; their ends were good and honorable; their calling lawful and urgent; and therefore they might expect the blessing of God in their proceedings."

Can we, with so much more at our disposal than they had, face an unknown future with any less courage, or any less faith?

AIEE WINTER GENERAL MEETING

January 21–25 were the dates for this year's Winter General Meeting of the AIEE. The program as is customary ranged over the many major fields of endeavor peopled by electrical engineers. Below we abstract a few of the papers more immediately interesting to the power field.

The Btu Computer

The general subject of analog computing instruments for industrial processes and specifically the Btu computer was covered by **Fred W. Hannula,** The Foxboro Co., in his paper, "The Btu Computer—An Advanced Data System for Industry." An industrial process, Mr. Hannula pointed out, is usually controlled by individually controlling all of its significant variables—temperatures, pressures and flows. The intelligence which establishes an optimum operation of the process must then be defined in terms of these variables.

So controlled, the process obviously requires the faithful performance of each unit. One variable out of control will upset the whole, for automatic readjustment of the other controllers is impossible. As a result, there is an increasing tendency to interlock several controllers to cause a mutual readjustment to meet changing needs. However, equivalent results can be often accomplished by manipulating measurements mathematically, in many cases reducing the multiplicity of controllers.

Often in a process, the parameter, which best describes its operation, cannot be measured directly, but can be defined mathematically in terms of two or more directly measurable

factors. Increasingly, these key parameters are determined and special purpose computers built to measure their values. The human operator is then supplied with more accurate and reliable information much more quickly than he could derive it from the "raw" data. And furthermore, automatic control can then be designed to produce a desired result rather than simply holding a group of variables within bounds. The Btu computer is such a special purpose system with a remarkably wide field of application.

The author then showed a conventional heat exchanger. This could have been part of a refrigeration system, a condenser, a chemical reaction vessel—or an atomic reactor. The common condition among them is an exchange of heat between two materials. For discussion purposes, the through line was shown containing a cooling fluid which gained heat. The Btu computer is said to be equally applicable when conditions are reversed, that is, when heat is removed from this fluid by the material inside the exchanger.

Electric Generation

Dr. E. Leonard Arnoff and **John C. Chambers,** Case Institute of Technology, joined forces to present the paper "Operations Research Determination of Generation Reserves." A prime requirement for an electric utility system is to be able to fulfill customer demands for power with some prescribed measure of reliability. Since future customer demands must be estimated and since generators and auxiliary equipment (boilers, turbines, etc.) are subject to forced outages, a utility system must maintain a reserve of installed generating capacity in the form of "extra" turbo-generator units. An important problem area, then, is that associated with the determination of a proper (or optimum) installed reserve generating capacity. Failure to have a sufficient reserve (sufficient, as measured by some criterion) leads to customer shortages with resulting customer dissatisfaction and loss of revenue, both direct and indirect. On the other hand, a surplus of generating capacity means additional inventory costs—costs associated with direct charges on idle or unnecessary capital equipment. It is important, therefore, to determine the best balance between these two costs, in the sense of minimizing the sum of the expected cost of a shortage and the expected cost of excess inventory. The determination of this optimum balance is equivalent to specifying when a new unit should be added so as to give the best reserve policy for the system.

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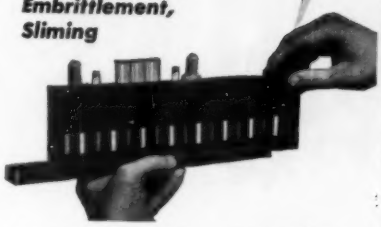

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An associated problem, and one for which an answer is, in a sense, already implied in the determination of the optimum reserve policy, is that of determining the optimum size (and type) of unit to be added to the system. Varying the size of the unit affects coal costs, maintenance costs, labor costs, holding costs, and so forth. Here, in considering large versus small units, one seeks a "best" balance between installation cost savings, coal savings and labor and maintenance savings, on the one hand, and increased cost of investment, on the other hand.

This paper attempted to present a method for determining the proper installed reserve generating capacity. It is a method that made use of various operations research techniques that have also been used in other areas.

The authors listed a number of basic assumptions and then commented that relative to the assumptions stated, the problem of determining an optimum reserve generation capacity could be reduced by determining:

(1) The joint probability of outages for the system.

(2) The expected customer demand on the system and the variability of this demand.

With the introduction of the large, high-pressure generating units that are being installed today, the authors maintain it is no longer possible to use a constant percentage in determining the reserve requirements. The reserve requirements may vary from 5 per cent for a system comprised of small units, to as high as 30–40 per cent for a system which has a large number of units over 200 Mw capacity and no source of additional power, such as from an interconnection.

Reserve capacity, these men aver, should be designed to provide for: (1) protection against loss of equipment because of forced outages, (2) scheduled maintenance, and (3) protection against errors in forecasting. In most of the literature these authors reviewed, little consideration was given to reserve generation for items (2) and (3) listed above. This report points out the necessity for reserve provisions for these elements. Scheduled maintenance was once not considered as a factor of any significance in the determination of reserve requirements, but, with the installation of large units, scheduled maintenance now becomes an important factor.

In calculating expected shortages, it is necessary to know expected total demand, consisting of customer demand, scheduled maintenance, and expected forced outages. The total

200-2

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demands are then compared with the total generating capabilities to see whether or not the expected shortage exceeds the maximum acceptable shortage, hence, whether or not additional generating capacity must be added to the system.

Automatic Dispatching

Two papers were presented on the subject of automatic dispatching, each having to do with a different operating utility.

R. H. Travers, Ohio Edison Co., reported his company's experiences in the paper "Automatic Economic Dispatching and Load Control—Ohio Edison System." In the fall of 1956, Mr. Travers stated the Ohio Edison placed in service a Power Dispatch Computer manufactured by Goodyear Aircraft Corporation, as an integral portion of its automatic system load control equipment. This computer, described in some detail in a paper presented before the AIEE in December, 1955, is located in the System Dispatcher's Office at Massillon, Ohio, and continuously determines the desired generation, or output, of each of the system's plants and feeds this information into the load-frequency control equipment.

The computer stores incremental heat rate data for each of 35 steam-generating units of the system, fuel cost data for each of the plants, and incremental transmission loss characteristics of the system, and by use of telemetered information of total system generation and interconnecting tie-line loadings combines all this information to give instantaneous solutions of the coordination equations for the economic dispatch of the system, which solutions are then fed in to the load-frequency control as the desired generation or "regulating point," for each of the plants.

The installation of the 1956 additional equipment at Burger Station of Mr. Traver's company has shown substantial savings due to correct allocation of generation at all times, and the savings easily offset the carrying charges of the additional equipment required. On this basis, similar equipment is now being installed in all other stations on the Ohio Edison system.

With the station load changes being allocated among the units automatically on the basis of incremental heat rates, it has been necessary for the station operator to closely watch the control action and periodically adjust the setting of the "rate of response" unit, dependent on how many units would be changing load over various ranges of plant output. This feature

has proven to be a limitation in the application of the incremental heat rate equipment, and the company now is preparing to install a "rate of response" unit on each individual generator. These will be simpler, single preset rate devices, as compared to the adjustable overall station devices. With this addition each generator will be individually protected.

The incremental heat rate data used in the station control equipment is the same data as used for the GEDA computer at the dispatcher's office. In this manner the output of each unit on the system is maintained at the correct values for the economic dispatch solutions without the necessity for closed loop feed back information from each unit to the dispatcher's office.

"Economic Aspects of the General Electric Automatic Dispatching System at Kansas City" by **D. H. Cameron,** and **E. L. Mueller,** Kansas City Power & Light Co., was the second paper in this category. These authors mentioned the difficulty of establishing a fixed criterion for determining probable fuel savings to be expected with any type control system. However, they felt it possible to compare fuel costs for an actual system operating condition with a theoretical loading schedule tempered by known system limitations such as reserve requirements, boiler firing conditions, minimum and maximum unit loads. Their paper described such a method used for evaluating the potential benefits available to an electric utility through the application of incremental loading of generating units, and compared that potential with those actually realized by such loadings. The control system and typical operating results obtained to date were also included.

The potential annual fuel savings of $68,000, shown available in the December, 1953 analysis, can probably never be fully realized on the Kansas City System. While the study did recognize the long time limitations inherent to the system, it could not foresee operating limitations imposed by regulating duty. In actual practice these necessitate operation at other than true incremental loading and undoubtedly account for a fair portion of the $45,000 annual fuel savings shown still available in a May, 1956 study. The most important of the limitations at Kansas City is that of the forced reductions in the rate of economic response and to some extent regulating response at the two older stations caused by a lag in boiler response and smoke control.

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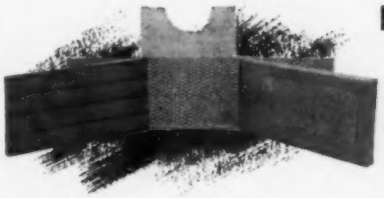

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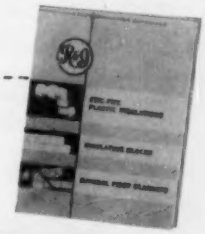

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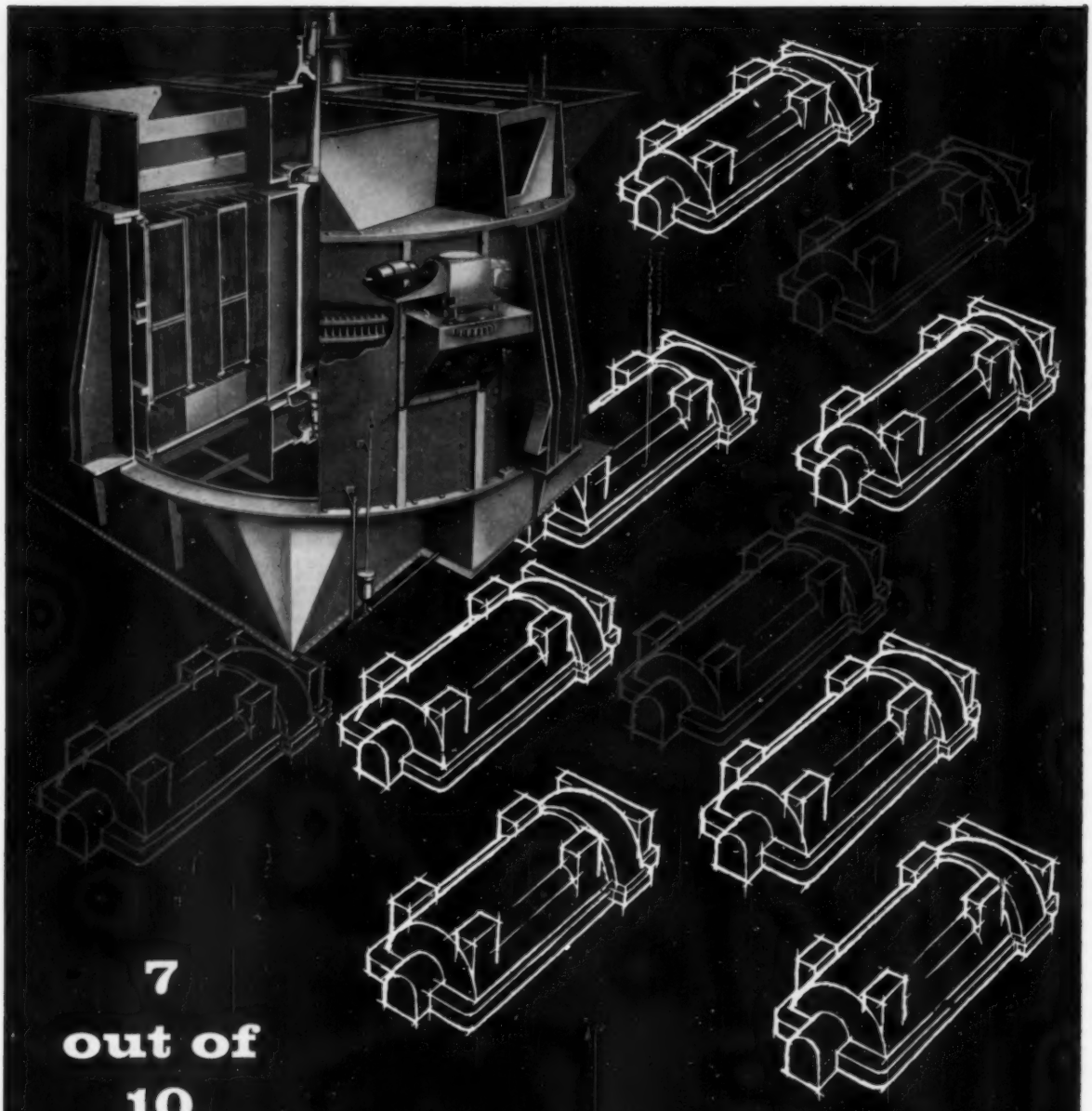

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BOOKS

1 Advanced Mathematics for Engineers

By H. W. Reddick and F. H. Miller

John Wiley & Sons, 548 pages, $6.50.

Now in its Third Edition this widely used book remains one of the most comprehensive and useful texts for teaching undergraduate engineers mathematical concepts beyond the level of differential and integral calculus. While it is intended for junior or senior students, it may also be useful to the graduate engineer for self-study. The inclusion of many worked-out examples and of answers to all problems enhances its value for the latter purpose.

Among the topics considered are ordinary differential equations, hyperbolic functions, elliptic integrals, infinite and Fourier series, partial differential equations, vector analysis, functions of a complex variable and operational calculus. Examples utilized to illustrate the mathematical principles are taken from all major areas of engineering. Concepts of units and dimensional analysis are discussed in an appendix.

2 Nuclear Fuels

By D. H. Gurinsky and G. J. Dienes

D. Van Nostrand Co., 364 pages, $7.50

At the 1955 Geneva Conference on the Peaceful Uses of Atomic Energy, a great deal of technical information was declassified and publicly presented for the first time. This book, which is one of a series on the Geneva Conference under the editorship of Dr. J. G. Beckerley, serves to bring together material from many papers. In so doing it aids the reader to obtain a broader understanding of the subject of nuclear fuels.

The book has been subdivided into three parts in order to acquaint the reader with the fundamental information necessary to design a fuel system, to point out problems specific to reactor systems and to show how the engineering requirements are fused to produce specific fuel systems. The three sections are entitled the metallurgy of uranium and thorium, radiation effects, and solid and liquid fuels.

References to Geneva Conference papers are keyed in at the beginning of each chapter to show the origin of the information. At the end of each chapter there are references to the open literature, and additional bibliographical items based on papers presented at the Nuclear Engineering and Science Congress in Cleveland, Ohio, in December 1955, are included as an appendix to the book.

3 Organic Chemistry Simplified; Second Edition

By R. Macy

Chemical Publishing Co., 612 pages, $12

This is a "learn-it-yourself" book which makes a relatively difficult scientific subject interesting through skillful writing. It is directed to persons who have completed the traditional first-year college course in inorganic chemistry and who may wish to undertake self-study in the field of organic chemistry.

The book is divided into four parts, of which the first, entitled "The Unique Position of the Carbon Atom in Chemistry," explains why carbon is so different from other elements. The second part, "The Architecture of Carbon Compounds," expands the theory of valence, discusses chain and ring compounds, and considers problems of nomenclature. In part three most attention is devoted, as its title suggests, to "The Classification of Carbon Compounds," including classification according to general structure, homologous series and composition. Part four, "Special Topics in Organic Chemistry," discusses the fundamental characteristics of proteins, dyes, sugars and related compounds. Most chapters conclude with a table of supplementary suggested readings.

While much of this book may seem to be elementary to the practicing chemist, it is written so interestingly that those on the fringe of the chemical field may find considerable intellectual stimulation in reading it. There are many other areas of science and engineering that could be made more intelligible using the approach developed by Dr. Macy, who is Chief of the Chemical Division, Chemical and Radiological Laboratories, Army Chemical Center.

4 Significance of ASTM Tests for Petroleum Products

ASTM Special Technical Publication No. 7-B 134 pages, $2.50

This is the third edition of this publication which concisely outlines the significance of the various ASTM methods of test related to petroleum products. It also calls attention to their limitations. It has been prepared for petroleum executives, scientists, engineers, laboratory technicians, and those concerned with the properties of petroleum products and the tests thereof. It will help them to acquire a general idea of the various methods of test and to understand performance characteristics of specific products and the significance of the properties of petroleum products in relation to one another. The language has been kept relatively free of technical terms.

Each chapter discusses a particular property or characteristic, covering the importance of sampling, selection of test apparatus, the methods of test which apply and their significance. Full details of the individual test procedures are not published in this volume, but are found in the annually published compilation "ASTM Standards on Petroleum Products and Lubricants."

The eleven chapters, determined by general properties, are arranged as follows: (1) Sampling Petroleum Products, (2) Measurement and Calculation of Volume, (3) Volatility, (4) Combustion, (5) Oxidation Characteristics, (6) Flow Characteristics and Solidification, (7) Corrosion, (8) Other Physical Characteristics and Tests, (9) Chemical Analyses and Tests, (10) Analysis for Hydrocarbon Types, and (11) Butadiene Analysis.

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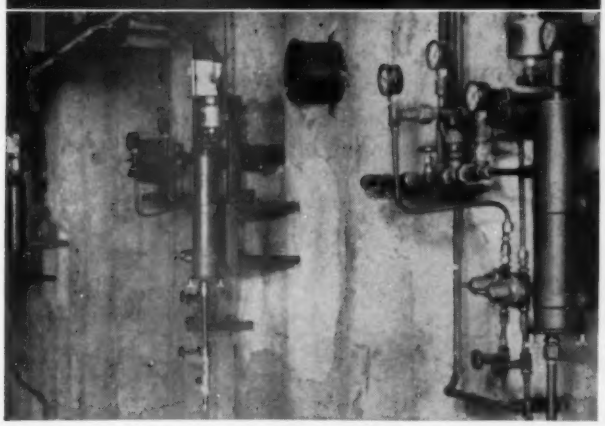

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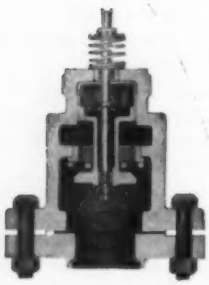

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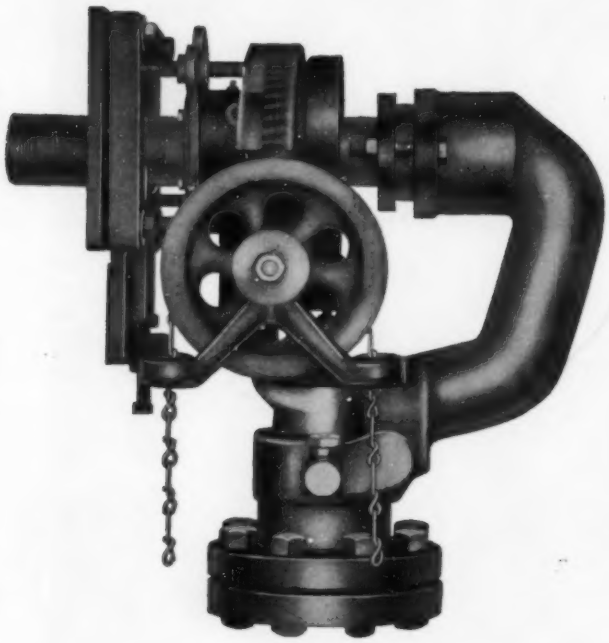

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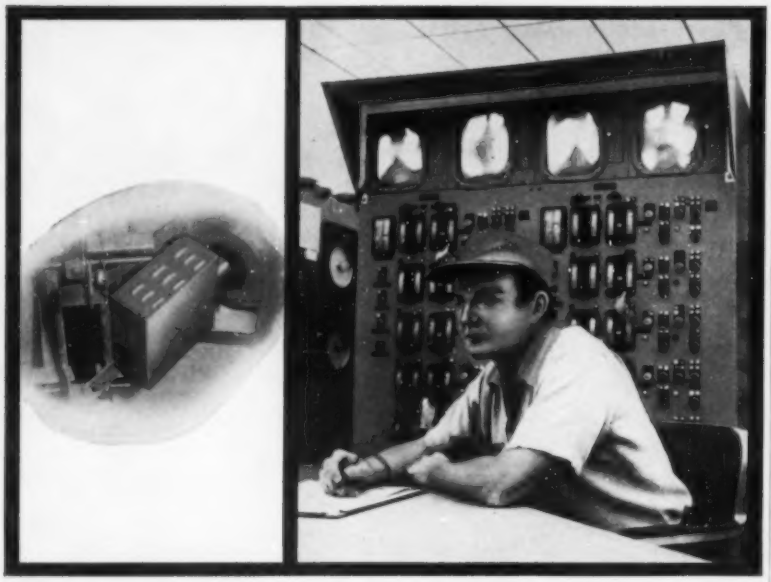

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6-240

KELLOGG'S FIELD CONTROL KEEPS PACE

(Above) An inspector on Kellogg's permanent staff supervises welding of main steam lines at the Glen Lyn Station. (Below) Controls for the gang of 40-kva stress relieving units at Glen Lyn provide a permanent record of preheating, concurrent heating, and stress relieving cycles, ranging from room temperature to 1350 F.

All high and low pressure steam piping for the 225,000-kw turbine-generator at Appalachian Electric Power Company's Glen Lyn, Virginia, station was fabricated and erected by M. W. Kellogg—using local union labor. Initial steam conditions are 1050 F, 2000 psi, with reheat at 1050 F. Main steam lines are 2¼% chrome-1% molybdenum, 12¾ in. OD, 2¼ in. average wall thickness. To meet the exacting requirements of both American Gas and Electric Service Corporation and The M. W. Kellogg Company, close control of techniques and procedures was doubly important.

At Glen Lyn, as elsewhere in the field, M. W. Kellogg's reputation for completing a power piping project efficiently and promptly is due to the right techniques, the right materials, the right equipment, and—equally important—the right men to train and supervise labor to Kellogg's special standards. We welcome the opportunity to demonstrate these unique abilities and facilities. Some of them, including K-Weld*, are described in our 12-page booklet, "For The Modern Central Power Station." Write for your copy.

Fabricated Products Division
The M. W. Kellogg Company, 711 Third Avenue, New York 17, N. Y.
A SUBSIDIARY OF PULLMAN INCORPORATED
The Canadian Kellogg Company Ltd., Toronto • Kellogg International Corp., London
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POWER PIPING—THE VITAL LINK

**Trademark of and patented by The M. W. Kellogg Company*

Dairyland Power Cooperative, Wisc.
The Franklin Heating Station,
Rochester, Minn.
Kansas City Power and Light Co.
Missouri Public Service Co.
Montana-Dakota Utilities Co.
Pacific Gas & Electric Co.

Central Illinois Public Service Co.
Commonwealth Edison Company
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NATIONWIDE!

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Mohawk Station, Tulsa, Okla.
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West Texas Utilities Co.

Carolina Power & Light Co.
Columbus & Southern Ohio Electric Co.
Georgia Power Company
Mississippi Power Company
Monongahela Power Company
South Carolina Public Service Authority

*Central Stations and Utilities use... Graver Deaerating Heaters**

A partial listing of tray and spray-tray type installations with capacities up to 2,250,000 lbs. per hour.

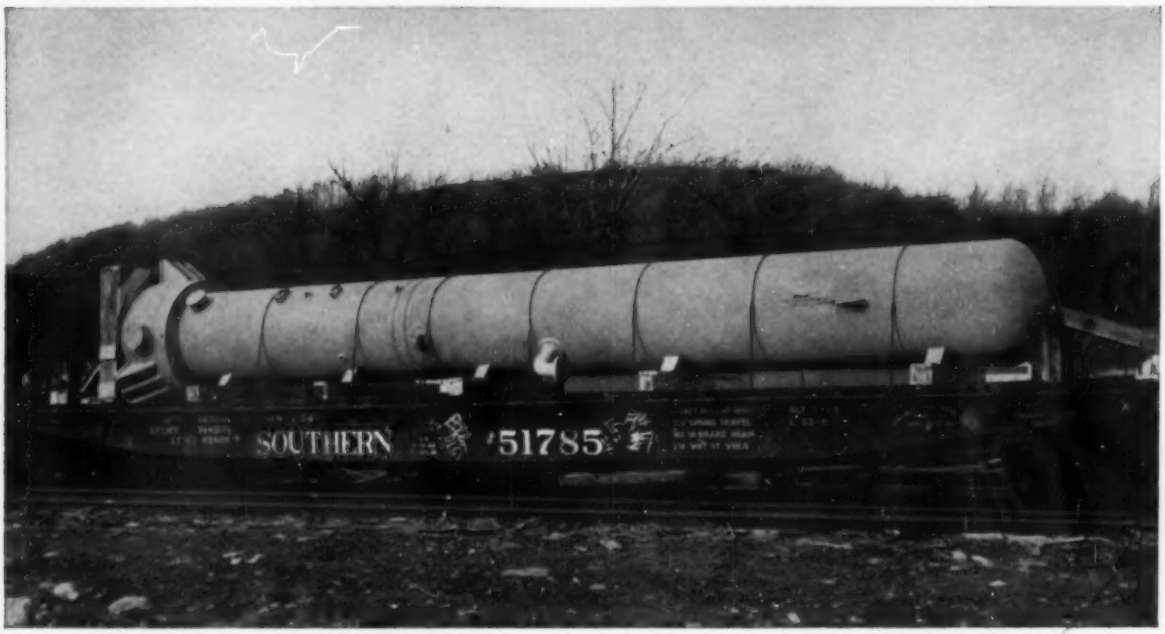
*WRITE FOR MANUAL OF POWER PLANT INFORMATION

A COMPLETE LINE OF WATER TREATMENT EQUIPMENT

GRAVER

Industrial Dept.: I-212

GRAVER WATER CONDITIONING CO.
Division of Graver Tank & Mfg. Co., Inc.
216 West 14th Street, New York 11, N. Y.



All-welded feedwater heater for new generating station will operate at 3200 psi with inlet steam temperature of 678° F. Designed and fabricated by The Lummus Company, the unit is the first of its kind, is also the biggest heater ever built for operation at pressures above 3000 psi, having 12,710 square feet of tube surface in a single shell.

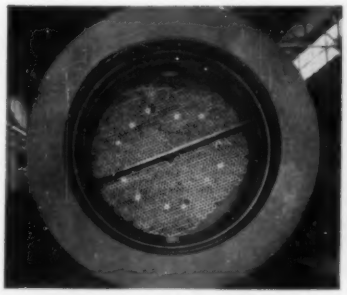
First All-Welded Feedwater Heaters Will Cut Generating Station Maintenance Costs

The first all-welded feedwater heaters ever built have been designed and fabricated by Lummus for the Linden Generating Station of the Public Service Electric and Gas Company of New Jersey. When completed, the installation will include 6 all-welded heaters, designed to operate at pressures well above 3000 psi, and 12 low pressure heaters which were all welded except for the tube to tube sheet joints.

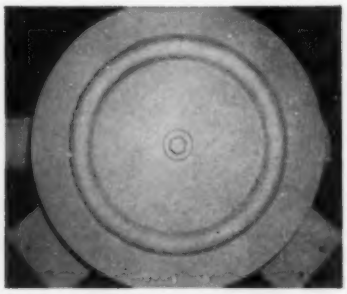
In addition, Public Service has just given Lummus a contract to supply feedwater heater requirements for their new Bergen Generating Station, duplicating in design the Linden units.

Welded construction minimizes leaks in tubes, shell and head. Thus the new units are expected to reduce materially the costly maintenance and downtime associated with failure of seals in bolted and gasketed constructions.

These unique heaters are the end result of over ten years of design and experimental work by The Lummus Company with all-welded fabrication. Perhaps this pioneering can help you reduce maintenance problems, too. For more information write The Lummus Company, 385 Madison Avenue, New York 17, New York.



Ends of cupro-nickel tubes are jointed to steel tube sheet by Inco "140" Monel Ni-Cu alloy electrodes. This alloy fuses well with both tube and sheet materials, forms strong, sound joint.



Closed head shows torus ring seal which is welded to channel and cover. Gasketed joint has been eliminated to avoid possibility of leakage. Design water pressure of unit is 3600 psi.

LUMMUS

HEAT EXCHANGER DIVISION

THE LUMMUS COMPANY, Heat Exchanger Division, 385 Madison Avenue, New York 17, N. Y. Atlanta • Boston • Chicago • Cincinnati • Cleveland • Dallas • Denver • Detroit • East Chicago (Indiana) • Houston • Kalamazoo • Kansas City • Los Angeles • Memphis • Minneapolis Nashville • New Orleans • Newton (Iowa) • Niskayuna (New York) • Omaha • Pittsburgh Salt Lake City • San Francisco • Springfield (Mass.) • Syracuse • Toledo • Wayne (Pa.) • Athens Buenos Aires • Caracas • The Hague • Lima • London • Mexico City • Montreal • Paris Rome • San Juan

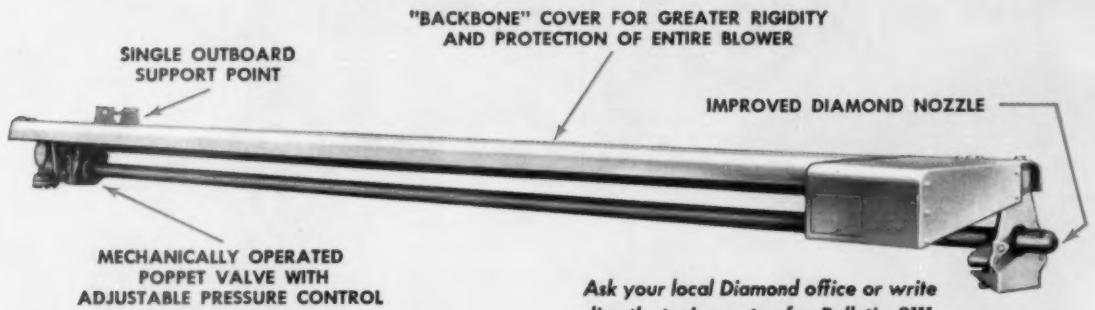
Steam Surface Condensers • Evaporators • Extraction Bleeder Heaters • Steam Jet Air Ejectors Steam Jet Refrigeration • Barometric Condensers • Heat Exchangers for Process and Industrial Use • Process Condensers • Pipe Line Coolers

Introducing DIAMOND SERIES 300 IK

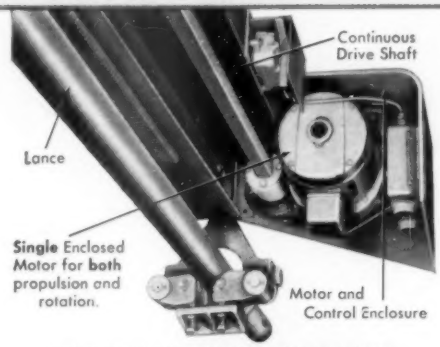
LONG RETRACTING BLOWER

Setting new and higher standards of efficiency, economy and dependability in the cleaning of heating surfaces that require a long retracting lance, the Diamond Series 300 IK Blower offers many outstanding features. Some of these are shown below. Others are: positive gear carriage drive . . . nozzle-sweep-every-inch cleaning pattern . . . oversize lance (step-tapered for extra long travel) . . . designed for quick, easy servicing.

This new blower is the culmination of more than 20 years experience building and applying long travel blowers. It well illustrates the Diamond design philosophy: "Keep it simple . . . keep it basic . . . avoid unnecessary complications." It is further evidence of the fact that YOU CLEAN BOILERS BETTER AND AT LOWER COST WITH DIAMOND BLOWERS.

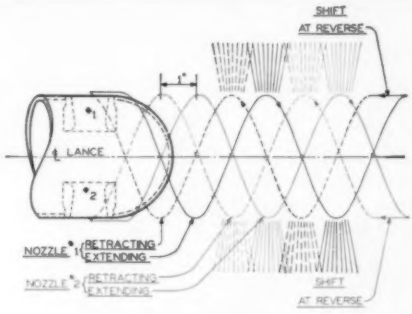

"BACKBONE" COVER FOR GREATER RIGIDITY AND PROTECTION OF ENTIRE BLOWER
SINGLE OUTBOARD SUPPORT POINT
IMPROVED DIAMOND NOZZLE
MECHANICALLY OPERATED POPPET VALVE WITH ADJUSTABLE PRESSURE CONTROL

Ask your local Diamond office or write directly to Lancaster for Bulletin 2111.



STATIONARY FRONT END DRIVE

A single stationary gear motor propels and rotates the lance. Power is supplied to the pinion and rack operated carriage by a drive shaft running the full length of blower. This construction makes it possible to mount motor in a fixed position at the front end for better protection and accessibility.



IMPROVE CLEANING PATTERN

Close and positively controlled helical cleaning pattern assures maximum cleaning effectiveness. Blowing pattern diagram illustrates how return travel path is exactly intermediate with forward travel path so that there is a *positive nozzle sweep every inch.*

Diamond

DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

DIAMOND SPECIALTY LIMITED—Windsor, Ontario

7740

how much could you add to your profit-- by saving $50,000 per boiler cleaning?

Here's An Example Of Such A Savings Made Possible By Dowell Chemical Cleaning Service

Dowell recently chemically cleaned a 1,000,000 lb. per hour steam generator for one of its customers. Total outage time was 48 hours. This saved the company an estimated five to seven days down-time, as compared to mechanical cleaning methods.

Considering replacement power for a boiler of this capacity costs between $7,000 and $15,000 per day, it's easy to see a $50,000 savings. And, it's just as easy to project a $250,000 to $500,000 annual savings for a plant with five to ten such boilers.

This particular case history concerns a power company with a forward-looking operations manager. But, Dowell has other startling performance data to show you — from your own industry. That's because chemical cleaning is so versatile. Dowell engineers are experts in removing scale and sludge from process systems, tanks and piping. They apply solvents in various ways— such as filling, jetting, cascading. Dowell furnishes all the necessary chemicals, trained personnel, pumping and control equipment.

For specific information on how chemical cleaning can help you to greater profits, call the Dowell office near you. Or write Dowell Incorporated, Tulsa 1, Oklahoma.

have Dowell clean it chemically DOWELL

A SUBSIDIARY OF THE DOW CHEMICAL COMPANY